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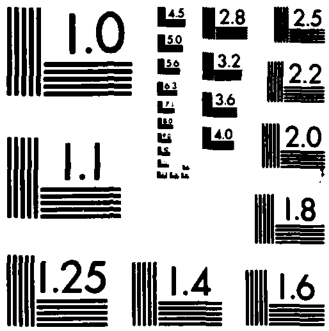

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DISCRIMINANT ANALYSIS OF RESPIRATORY SOUNDS OF PULMONARY INSUFFICIENT PATIENTS AND NORMAL SUBJECTS

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NOTICES

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The voluntary fully informed consent of the subjects used in this research was obtained as required by AFR 169-6.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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Respiration is one of the physiological functions of concern when a patient is under examination or treatment. A clinical relationship between respiratory sounds and gross respiratory pathology was established in the nineteenth century. Previous research indicates that respiratory sounds measured at the trachea undergo very little filtering. Charbonneau stated that the sound level is higher at the trachea than at any other point of the chest or back and the localization of the point is more precise. Therefore, recordings of the respiratory sound for this study were obtained from the area of the trachea.

The objective of this study is to determine whether respiratory sound data of normal volunteers and pulmonary insufficiency subjects can be classified as normal or abnormal pulmonary systems by discriminant analysis and if the spectral parameters for discriminating respiratory sounds correlate with clinical parameters obtained from the pulmonary function test. Patient data was obtained from the U.S. Air Force School of

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Aerospace Medicine, Brooks Air Force Base, Texas. The classification (normal/pulmonary insufficiency) of the subjects was determined from a single pulmonary function test.

The results of the discriminant analysis are encouraging from the standpoint that classification with mean expiratory data closely approximates results from classification with the 3 pulmonary function test variables. In addition, we concluded that classification with the mean data is better than classification with data based on each breath. Finally, from the regression studies, we concluded that there appears to be minimum or no correlation between the respiratory sound spectral parameters (MPF, FPK, and FMAX) and the three pulmonary function test parameters (FVC, FEV1, and FEV1P).

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DISCRIMINANT ANALYSIS OF RESPIRATORY SOUNDS OF PULMONARY INSUFFICIENT PATIENTS AND NORMAL SUBJECTS

INTRODUCTION

Respiration is one of the physiological functions of concern when examining or treating a patient. A clinical relationship between respiratory sounds and gross respiratory pathology was established in the nineteenth century. Auscultation of respiratory sounds, however, is subjective. Due to the subjectiveness, there are varying degrees of acceptance of respiratory sounds as a clinical sign. To alleviate the problem, various researchers have studied respiratory sounds to explore and develop automated methods for analysis and diagnosis of pulmonary diseases.

The objective of this study is to determine whether respiratory sound data of normal volunteers and pulmonary insufficiency subjects can be classified as normal or abnormal pulmonary systems by discriminant analysis and if the spectral parameters for discriminating respiratory sounds correlate with clinical parameters obtained from the pulmonary function test. Patient data was obtained from the U.S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Texas. The classification (normal/pulmonary insufficiency) of the subjects was determined from a single pulmonary function test.

Background

The process of respiration is of vital importance to life and includes the following mechanistic events: (1) pulmonary ventilation, the inflow and outflow of air between the atmosphere and the lung alveoli, (2) diffusion of oxygen and carbon dioxide between the alveoli and the blood, and (3) transportation of oxygen in the blood, principally in combination with hemoglobin, to the tissue capillaries where it is released for use by the cells according to their metabolic needs [17].

The foundations of respiratory medicine were laid at the beginning of the nineteenth century when Laennec [20] established the clinical relationship between respiratory sound and gross pulmonary pathology by the use of the early stethoscope. Auscultation in respiratory medicine, however, has advanced slowly since Laennec established auscultation of lung sounds as a means of diagnosing the condition of the lungs.

The slow progress is due to: (1) a variety of human factor problems, (2) the limitations of the instrumentation, (3) the lack of total understanding of the mechanism of production of respiratory sounds, and (4) the lack of understanding of the origin of the source of the sounds.

Human Factor Problems

Respiratory sounds heard through a stethoscope can be roughly classified into two main types: First are normal respiratory sounds,

these are both inspiratory and expiratory sounds heard as the air moves in and out of the chest during normal breathing. There are two types of normal respiratory sounds. Tracheal or bronchial respiratory sounds are heard by placing the stethoscope over the trachea and listening as the patient breathes in and out with the mouth open. The sound is described as "tubular" and is similar to the sound that arises when air is blown through a tube. The other major type of respiratory sound is called vesicular. The term "vesicular" in Latin refers to little vessels. This description refers to the sound that is heard over the majority of the chest of normal persons during normal breathing. The analogy used is the sound heard by the rustle of wind in the trees [9].

The term "adventitious" is used to describe sounds not expected in the normal chest. To complicate matters, the terminology of adventitious sounds is not standard. The clinician attempts to describe the quality of sounds by adjectives that convey an idea of relative intensity and pitch. Different clinicians use the same term to describe dissimilar sounds [1,9].

Adventitious sounds are divided into those believed to have a bronchopulmonary origin and those thought to be due to pleural disease. Those of bronchopulmonary origin are further subdivided into "continuous" and "discontinuous". Sounds that last for more than a tiny fraction of the respiratory cycle are referred to as continuous. Rales, the discontinuous sounds, are further subdivided into fine, medium, and coarse. A variety of adjectives appear in the medical literature to classify these sounds further. Examples of these adjectives include dry, wet, moist, bubbling, crepitant, subcrepitant, and consonating. The terminology is subjective in its interpretation depending greatly on the hearing and experience of the clinician [1,2,12,13,25-27].

Another problem in chest auscultation is that so much information exists that it is difficult either to record it properly or to remember the observed details. On listening over a single site in the chest, it is possible to observe the intensity of both inspiration and expiration. It is also possible to grade these on a scale that may reflect normality or abnormality of the site. The clinician may also be able to record the presence or absence of various adventitious sounds and their relationship to the respiratory cycle. The duration of inspiration with respect to expiration may also be noted. If the clinician listens to one or more sites, as is common in routine chest auscultation, then there is a possibility that information may be lost due to various factors such as interruptions in the physical examination, lack of accurate record keeping, or the clarity of the clinician's initial observations [25]. The diversity of the terms used to describe respiratory sounds, together with the nonuniformity of their usage by clinicians, poses difficulties in the use of respiratory sounds as a precise indicator of the condition of the respiratory system.

Limitations of Instrumentation

The binaural stethoscope appeared towards the middle of the nineteenth century and became popular mainly because it excludes extraneous noise [15,24]. The choice of the best chest piece remained controversial until physicians agreed that both the diaphragm and the bell were necessary for auscultation of the heart. The diaphragm and bell are combined in most stethoscopes in current use.

The stethoscope transmits the range of frequencies which includes frequencies of heart and lung sounds. By varying the pressure between the chest piece and the skin, the intensities of certain frequencies are increased while others are decreased. Low-pitched heart sounds are heard best with the bell resting lightly on the skin, while firm pressure of the bell or diaphragm increases the intensity of higher frequencies and suppresses unwanted low-pitched sounds. Respiratory sounds contain a wide range of frequencies. To compare relative frequency intensities within a particular sound spectrum, the measuring instrument should not contribute variations in intensity. The conventional stethoscope exhibits this limitation [11,25].

Sound evaluation is further complicated by the nonlinearity of the human auditory system. The ear is capable of distinguishing small differences in pitch. As the intensity of the sound increases, the sensitivity of the ear to intensity variations decreases logarithmically. The ears' perception of intensity falls off at both ends of the frequency spectrum [11]. The frequencies of sound that a young person can hear differ from the frequencies of sound that an older person can hear. The range falls between 30 and 20,000 cycles per second(cps) for a young person and 50 to 8,000 cps in old age [16]. The ear is unable to distinguish short sound bursts. A burst shorter than 3 ms will be heard only as a click regardless of the frequency [13].

Electronic instruments can be designed to exhibit a flat frequency response over the range of respiratory sound spectrum and thus overcome some of the instrumentation shortcomings. The major obstacles, however, in the acceptance and advancement of using respiratory sounds as a major clinical tool in pulmonary medicine are the lack of complete understanding of the mechanism of production of respiratory sounds, and the sources from which respiratory sounds are generated.

Since Laennec's time it has been known that pulmonary pathology can cause a change in respiratory sound. Differences exist between normal and pathological respiratory sounds. In 1976, Grassi et al. [15] used the technique of phonopneumography to analyze respiratory sounds. Phonopneumography is defined as the technique of detecting and analyzing the sounds that are produced in the bronchopulmonary area during respiration. The apparatus used was intended to provide a graphic recording of the level of the sounds the clinician perceives through the stethoscope during auscultation. The phonopneumographic records revealed that inspiration was louder than expiration in the healthy subjects. Wherever the ratio between inspiratory and expiratory peak amplitudes was

found to be highly modified, either because inspiration was much louder than normal, or because an inversion of the ratio occurred with an expiratory sound louder than inspiratory, the finding was always accompanied by pathological alteration of the pulmonary zone.

Chowdhury and Majumder [4] conducted an experiment using digital spectral analysis of respiratory sounds for the purpose of determining the clinical relationship between the frequency spectrum and the conditions of the lungs in pulmonary diagnosis. Their study included 6 normal subjects and 6 tuberculosis patients with fibrosis. The recordings of respiratory sounds were made in a quiet room with the subject in the supine position and the microphone placed on the right lung base. The Fast Fourier Transform(FFT) algorithm of Cooley and Tukey was used to obtain the normalized autospectrum of 0.25 s time segments of respiratory sound. Their analysis indicates a maximum amplitude of about 250 Hz for subjects without pathological lung history, with rapid decrease in amplitude as the frequency increases and approaches 1000 Hz. In the case of the tubercular lung, a downward frequency shift of amplitude peak and the presence of higher frequency components were observed.

Charbonneau et al. [3] developed an index which they used to discriminate between asthmatics and normal subjects. They calculated the average spectrum for inspiration and expiration and referred to it as a histogram. Four parameters for both expiratory and inspiratory histograms were calculated and the sum of the parameters was used as an index to discriminate between asthmatics and normal subjects. The parameters were: the bandwidth (taken at half of the peak amplitude), the integral over the range 60-1260 Hz, the highest significant frequency (taken to be 10% of the amplitude of the peak frequency), and the weighted mean frequency of each mean spectra. Their study included 11 normal and 10 asthmatic subjects.

Problems with Sound Intensity Recorded from Chest Wall

The correlation of respiratory sound intensity and the distribution of pulmonary ventilation was first studied by Leblanc et al. [21]. They concluded that the intensity of respiratory sounds varied with lung volume, flow rate, body orientation, and the site of the recording. O'Donnell and Kraman [28] and Dosani and Kraman [7] conducted studies to investigate the intensity patterns of lung sound on the chest wall. They concluded that there was a considerable intersubject and intrasubject variability in amplitude of the inspiratory vesicular sound heard on the chest wall, and that the variability was due to factors other than the distribution of ventilation and chest wall thickness. These variations happen even with normal subjects without any diseases of the lung. They believed that the other factors included the site of production of these sounds and their transmission through the airways and lung tissue. Dosani and Kraman (7) pointed out that the chest wall thickness may not have a predominant effect on the intensity. Their results showed that sound intensity at the lateral wall was similar to sound at positions near the spine where the thickness of the chest wall is greater.

Rationale for Trachea as Site of Respiratory Sound Detection

The variability of acoustic properties of the chest wall account for the variability of sound intensity as measured at the chest wall [3,8,16,29,30]. Previous research indicates that respiratory sounds measured at the trachea undergo minimum filtering [3,8,16]. Charbonneau [3] stated that the sound level is higher at the trachea than at any other point of the chest or back and localizing the point is more precise. Therefore, recordings of the respiratory sound for this study were obtained from the area of the trachea.

EXPERIMENTAL PROCEDURES

Data were obtained from the USAF School of Aerospace Medicine and were collected by USAF personnel at Wilford Hall USAF Medical Center on patients with pulmonary insufficiency and on normal volunteers. Patients were classified from results of their pulmonary function test (PFT). The experimental procedure used by the U.S. Air Force for data collection was as follows.

The patient was instrumented with a pulmonary flowmeter that was comprised of two Fleisch pneumotachometers with a Rudolph valve between them and connected to a mouthpiece. One pneumotachometer was used to transduce the inspiratory flow rate and the other one was used to transduce the expiratory flow rate. The pneumotachometer devices had pressure taps that were connected to Validyne pressure transducers. An electronic stethoscope was held at the anterior cervical triangle for the detection of respiratory sounds. The patient breathed through the flowmeter exclusively, using a nose clip to prevent nose breathing. A minimum of 5 min of recording time for each patient was collected to allow the patient to become accustomed to the apparatus and to establish a normal breathing pattern. The respiratory sounds and the flow rate were transduced and recorded on an FM analog tape recorder.

Experimental Procedure for Data Analysis

The magnetic tapes were under contract to Texas A&M University, Bioengineering Department for data analysis. Since the classification (normal/pulmonary insufficiency) of the subject, number of subjects, and location of each subject in relation to the time code was not well controlled by the U.S. Air Force, the study results suffered. Of the 35 subjects, only 24 could be identified. Not all subject records contained their PFT or their classification.

The equipment used in the analysis of the magnetic tapes consisted of the following components:

- Ampex 2200 FM analog tape recorder
- Datum Time Code Generator/Reader Model 9300
- 20-Hz, 1800-Hz low-pass filters
- 100-Hz high-pass filter

- A/D Multiprogrammer (HP 6942A)
- Tektronix 5A22N Differential Amplifier
- Tektronix 5111A Storage Oscilloscope
- Tektronix 2236 (100 MHz) Storage Oscilloscope

The arrangement of the equipment used for analysis of inspiratory and expiratory data is shown in Figure 1.

Inspiratory Data Analysis

As shown in Figure 1, the respiratory sound signal and the inspiratory flow-rate signal were monitored simultaneously on an oscilloscope. The magnetic tape speed was 3-3/4 in./s. Recordings were made with standard Inertial Rate Integrating Gyro (IRIG) intermediate band record/reproduce amplifiers with a cutoff frequency (3 dB) at 19 kHz and a signal-to-noise ratio of 35 dB (root-mean-square(rms) signal-rms noise). Channel 10 of the FM recorder was connected to the time decoder to display the recorded time. The time decoder was monitored until a valid time code was displayed, indicating a subject's data were recorded on Channel 2 (inspiratory flow data) and on Channel 4 (respiratory sound data) of the magnetic tape. Then, the time code and signals were simultaneously monitored and the total length of the subject's inspiratory data was recorded. The total length of time was assumed to be the time between the beginning of a time code and the time when the time code cleared. Then, the time of each inspiratory breath was also recorded. A calibration procedure was performed on the inspiratory flow-rate signal to calculate the gain that was used. Transducer transfer gain (volts/liters/second) is multiplied times recording gain (X1) and playback equipment gain (G_p) to yield "overall gain" (G_t). Voltage levels divide by G_t results in physical units of flow in liters/second. This value was used in making the graphs of flow vs. time. Flow in voltage levels (or analog to digital (A/D) counts) were used to trigger collection of respiratory sounds. For a specific inspiratory breath the signal on the magnetic tape was viewed on an oscilloscope and the voltage of the signal was recorded. The signal from the output of the 20-Hz filter for the same inspiratory breath was viewed on another oscilloscope simultaneously and the voltage of the signal was recorded. The gain was calculated by the ratio of the voltage recorded from the output of the 20-Hz filter to the voltage recorded directly off the magnetic tape. The value of the gain was necessary in determining the correct inspiratory flow rate. This procedure was done prior to inspiratory data collection for each new subject.

The inspiratory flow-rate signal was taken from Channel 2 of the FM recorder and fed into the 20-Hz low-pass filter. The output of the filter was fed into both the oscilloscope for monitoring and the analog input box for manual triggering. The output of the analog input box was then fed into Channel 2 of the A/D converter.

The inspiratory sound signal was taken from Channel 4 of the FM recorder and fed into a 100-Hz high-pass filter followed by a 1800-Hz low-pass filter. The output of the filter was fed into both the oscilloscope for monitoring and into Channel 1 of the A/D converter. After calibration

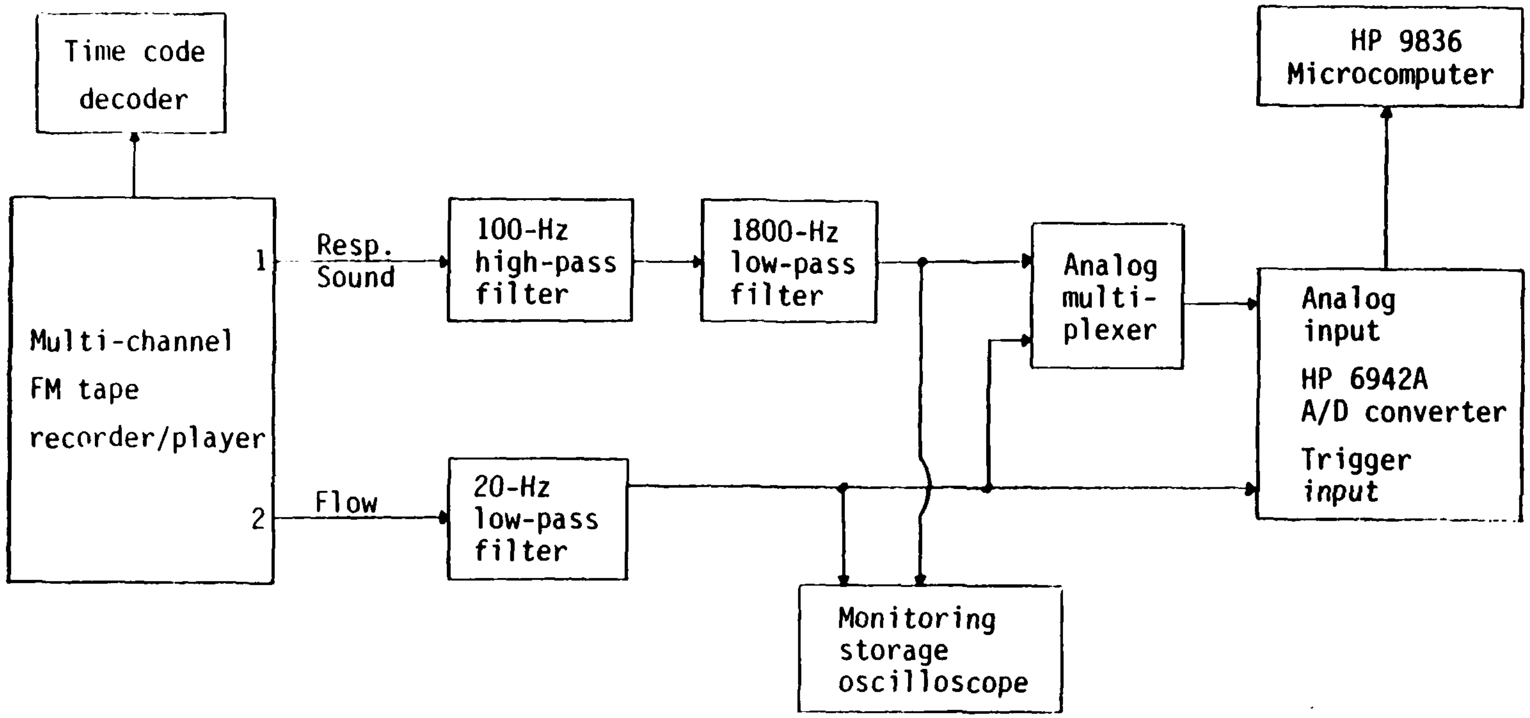

Figure 1. Block diagram of equipment setup.

of the flow data and random selection of four breaths, data collection began.

The HP-9836 desktop microcomputer was programmed to monitor the inspiratory flow rate via the A/D channel and begin data collection when the flow rate reached a predetermined level. The level was determined by viewing the signal on the oscilloscope. Data collection was handled by the multiplexed A/D channel at the sampling rate of 8192 samples per second. By choosing a sampling rate of 8192 samples per second, the result was to sample each analog channel (respiratory sound and flow rate) at 4096 samples per second. The program was modified to be interactive; therefore, it allowed for versatility in the processing of recorded data with large variabilities. The program prompted the operator for changes of the flow rate trigger level, the duration of data collection, the number of repetitions, the data file name, the data file structure, and the sampling rate. The program also had additional flexibility that allowed the operator to decide whether or not to save the data that was collected. Much of the data contained extraneous noises (i.e., talking, babies crying, door slamming, etc.).

The voltage level at which the A/D converter started collecting data was displayed on the screen. If the level was acceptable with the trigger level that was set (within 0.2 V), then the data were saved and stored on the diskette. The data file names used were the respective time codes of the breaths collected. This procedure continued until 4 inspiratory breaths of each subject had been collected, digitized, and stored on diskettes for further signal processing.

Expiratory Data Analysis

As shown in Figure 1, both the expiratory flow-rate signal and the expiratory sound signal were monitored simultaneously on an oscilloscope. The same procedure for locating the inspiratory data was used to locate expiratory data.

A calibration procedure was then performed on the expiratory flow-rate signal to calculate the gain that was used. For a specific expiratory breath, the signal off the magnetic tape was viewed on an oscilloscope and the voltage of the signal was recorded. The signal from the output of the 20-Hz filter for the same expiratory breath was viewed on an oscilloscope and the voltage of the signal was recorded. The gain was calculated by the ratio of the voltage recorded from the output of the 20-Hz filter to the voltage recorded directly off the magnetic tape. The value of the gain was necessary in determining the correct expiratory flow rate. This procedure was done prior to expiratory data collection for each new subject.

The expiratory flow-rate signal was taken from Channel 3 of the FM recorder and fed into the differential amplifier of the oscilloscope. The differential amplifier was used to balance the direct current (DC) offset by adjusting the DC step attenuation balance and the position knob. The filter setting was DC. This step was needed because the expiratory flow

transducer that was used had a 1.4 V DC offset. The output of the oscilloscope was fed into the input of the 20-Hz filter, and the output of the 20-Hz filter was fed into both the oscilloscope for monitoring and the analog input box for manual triggering. The output of the analog input box was then fed into Channel 2 of the A/D converter. The respiratory sound signal was taken from Channel 4 of the FM recorder and fed into a 100-Hz high-pass filter followed by a 1800-Hz low-pass filter. The output of the filter was fed into both the oscilloscope for monitoring and into Channel 1 of the A/D converter.

The same procedure of expiratory data collection using the HP-9836 microcomputer and A/D converter as noted for the inspiratory data collection was used. This procedure continued until 4 expiratory breaths of each subject had been collected, digitized, and stored on diskettes for further signal processing.

QUANTITATIVE ANALYSIS

The Fourier series is used to represent arbitrary periodic functions by an infinite series of sinusoids of harmonically related frequencies to study the time domain responses in networks. The Fourier series expressed as a linear combination of harmonically related complex exponentials can be written in the form:

$$x(t) = \int a_k e^{-jk\omega_o t}\, dt \tag{1}$$

$$a_k = 1/T_o \int x(t) e^{-jk\omega_o t}\, dt \tag{2}$$

where $k = 1, 2, \ldots, \infty$.

Equation (1) is often referred to as the synthesis equation and equation (2) as the analysis equation. The coefficients, a_k, are often called the Fourier series coefficients or the spectral coefficients of $x(t)$. These complex coefficients measure the portion of the signal $x(t)$ that is at each harmonic of the fundamental component. The fundamental frequency is defined as ω_o, and the fundamental period is $T_o = 2\pi/\omega_o$.

The Fourier series method, however, has limitations in analyzing linear systems for the following reasons: 1) The Fourier series can be used for inputs which are periodic; however, most inputs in practice are nonperiodic. 2) The method applies only to systems that are stable. A stable system is a system whose natural response decays in time.

The first limitation can be overcome since we can represent the nonperiodic input in terms of exponential components. A method of accomplishing this function is the Fourier transform. For instance, consider the nonperiodic function $f(t)$ which we would like to represent in terms of exponential components. To do this, we constructed a periodic function $f_T(t)$ with a period T, where the function $f(t)$ is repeated every T seconds. The period T, is considered large enough so there is no overlapping between pulse shapes of $f(t)$. The new function is a periodic

function and can be represented with an exponential Fourier series as follows:

$$f_T(t) = \Sigma F_n e^{jn\omega_o t} \tag{3}$$

$$\text{where } \omega_o = 2\pi/T, \tag{4}$$

$$\text{and } F_n = 1/T\ \Sigma\ f_T(t)e^{-jn\omega_o t} \tag{5}$$

The next process is to evaluate the function as the period increases to infinity. As T becomes infinite, the pulses repeat after an infinite interval. Therefore, $f_T(t)$ and $f(t)$ are identical in the limit, and the Fourier series representing the periodic function $f_T(t)$ will also represent $f(t)$.

In the limit, as T approaches infinity, ω approaches zero. Therefore, ω_o can be denoted as $\delta\omega$. Then: $T = 2\pi/\omega_o = 2\pi/\delta\omega_o$ and,

$$TF_n = \Sigma f_T(t)e^{-jn\delta\omega t} \tag{6}$$

TF_n is a function of $jn\delta\omega$, so let $TF = F(jn\delta\omega)$. Equation (3) becomes:

$$f_T(t) = \Sigma\ F_n e^{jn\omega_o t} \tag{7}$$

$$= \Sigma[F(jn\delta\omega)/T]e^{(jn\delta\omega)t} \tag{8}$$

$$= \Sigma\{[F(jn\delta\omega)/2\pi]\delta\omega\}\ e^{(jn\delta\omega)t} \tag{9}$$

In the limit, as T approaches infinity, $\delta\omega$ approaches zero, and $f_T(t)$ approaches $f(t)$. Then:

$$f(t) = \text{Lim}\ \ f_T(t) = -\text{Lim}\ \ 1/2\pi\ F(jn\delta\omega)\ e^{jn\delta\omega t}\delta\omega] \tag{10}$$

is by definition:

$$f(t) = 1/2\pi \int F(j\omega)e^{j\omega t}\ d\omega \tag{11}$$

Equation (11) is known as the inverse Fourier transform. Recall equation (5):

$$F_n = 1/T \int f_T(t)e^{-jn\omega_o t}\ dt \tag{12}$$

$$= F(jn\delta\omega)/T \tag{13}$$

then

$$F(j\omega) = \text{Lim} \int f_T(t)e^{-jn\delta\omega t}dt \tag{14}$$

$$F(j\omega) = \int f(t)e^{-j\omega t}\ dt \tag{15}$$

Equation (15) is known as the direct Fourier transform. The result is that

$$F(j\omega) = \int f(t)e^{-j\omega t}\ dt \tag{16}$$

is the representation of the nonperiodic function f(t) in terms of exponential functions. The amplitude of the component of any frequency ω is proportional to $F(j\omega)$. In analogy with the terminology used for the Fourier series coefficient of a periodic signal, the transform $F(j\omega)$ of an aperiodic signal f(t) is commonly referred to as the spectrum of f(t), as it provides the information concerning how f(t) is composed of sinusoidal signals at different frequencies.

The second limitation applies to nonstationary data from a system. During normal respiration the respiratory system is stable. If the signal from a system is stationary, the system may be assumed to be stable. Weak stationarity is shown in the ergodic sense by averaging several records of an individual at one time and averaging another set from the same subject at a different time, if the means and autocorrelation are invariant the data is weakly stationary. This procedure was shown in the statistics in reference 34. Hence, for this study the data is assumed to be stationary, which is the case for mean data, but not necessarily for individual sample data.

In the study, the respiratory signal was conditioned by the use of the analog filters previously discussed in the experimental procedures. The 100-Hz high-pass filter and the 1800-Hz low-pass filter were thus acting together as a band-pass filter. The respiratory sound data and flow data were digitized, separated using the separation program, and stored on diskettes for the Fast Fourier Transform (FFT) analysis. The respiratory sound signal was digitized at a rate of 4096 samples/second. The sampling rate was chosen to avoid "aliasing" of the spectra. The literature indicates that the highest frequency of normal respiratory sound is about 1500 Hz, and this may be higher for abnormal subjects. The Nyquist sampling criteria requires that the Nyquist frequency be at least twice the highest frequency of interest of the signal being sampled. The first 1024 samples, which correspond to 0.25 s of real-time data, were transformed by the Cooley-Tukey FFT algorithm.

When only a finite segment of the signal is observed, the process is equivalent to multiplying the signal by a rectangular window function. In the frequency domain, this multiplication becomes a convolution between the desired spectrum and that of the window. As a result, the frequency spectrum is distorted, and the spectral components "leak" away from their time frequencies and are distributed over the total spectrum [32]. A rectangular window function is not accurate in describing the signal, and therefore produces signal discontinuities at the boundaries. The FFT will add all harmonics to simulate the fast rising edge of the window, and this is inaccurate in representing the signal. Frequency distortion occurs when part of the true frequency is distributed to the side lobes. A rectangqular window results in a sharper cutoff, more narrow main lobe, but the 1st side lobe is only -13 dB down with the remaining side lobes decreasing at -6 dB/octave. The Hanning window, which is often called the cosine window, reduces the side lobe level to -32 dB with a -18 dB/octave roll-off in the side lobes. A suitable window function needs to be chosen to minimize the "spectral leakage". The window chosen was a 10% cosine tapered window. This window forces the first data point to zero, and the

rising edge of the window is a cosine function. A correction factor of $G_i = G_i/0.875$ is applied to the spectrum resulting form the modified cosine window as suggested by Bendat. Discontinuities in general lead to the "Gibbs phenomenon" which infers that even with an infinite Fourier series there will be a 9% error at the discontinuities.

The power spectrum is computed from the square of the resulting Fourier coefficients.

$$G_i = C_i^2 = (a_i+jb_i)(a_i-jb_i) \tag{17}$$

$$G_i = C_i^2 = a_i^2 + b_i^2 \tag{18}$$

Calculation of Parameters

Three indices of measure were calculated from the power spectrum. These parameters were the mean frequency of the power spectrum (MPF), the frequency of the maximum power (FPK), and the highest frequency at which the power in the spectrum equals or is less than 10% of the maximum power (FMAX). The rationale for selecting these parameters is:

(1) In descriptive statistics, the mean (MPF) corresponds to the central tendency of the distribution.

(2) The peak value (FPK) or the mode of a distribution corresponds to the most frequent occurrence of an event, in this case the power within the respiratory sound spectrum.

(3) The highest frequency (FMAX) at which the power in the spectrum becomes 10% of the peak power corresponds to a rough bandwidth from DC to the frequency at which the power contents remain 10 dB below FMAX in the spectrum. This parameter may also be used as an indicator of the correctness in the selection of the Nyquist sampling frequency. In addition, Charbonneau et al. [3] used the FMAX parameter as part of a linear function to discriminate normal patients from asthmatic patients.

The mean frequency of the power spectra was calculated from the equation:

$$MPF = \Sigma(C_i^2 * F_i)/\Sigma C_i^2 \tag{19}$$

where i is the index 0, 1, 2,....., N-1.

F_i is the frequency at index i, and C_i is the Fourier coefficient at index i. The coefficient C_i is computed from the FFT:

$$C_i = (a_i^2+b_i^2)^{1/2} \tag{20}$$

where a_i is the real component of the Fourier coefficient at index i, and b_i is the imaginary component of the Fourier coefficient at index i.

The next parameter calculated by the program is the frequency of the FMAX of the power spectrum. A sorting routine is used to locate the FMAX and the index at which the FMAX occurred. The peak frequency then becomes

$$FP = I*FR \tag{21}$$

where I is the index 0,2,...,N-1, and FR is the frequency resolution (FR). The FR is calculated from the period or window length in time, that is:

$$FR = 1/(0.25\ s) = 4\ Hz \tag{22}$$

The final parameter, the highest frequency at 10% of the FMAX, is calculated in a manner similar to the calculation of the frequency of the FMAX. Again, a sorting routine is used to find the index at which the power becomes 10% of the FMAX; then the frequency is calculated from the index.

DISCRIMINANT ANALYSIS

A basic problem in clinical diagnosis is that of assessing and classifying individuals based on a number of physiological attributes. This process requires well-defined, mutually exclusive classes, to one of which the individual in question must belong.

Several decision-making procedures, varying somewhat in approach, complexity, and overall effectiveness, are applicable to the classification of observed data. Discriminant analysis is a method of assigning an observation to 1 of 2 or more distinct groups. Discriminant analysis is often viewed as a technique for the description and testing of between-group differences [5]. Yet others view discriminant analysis as a problem of assigning an unknown observation to a group with low-error rate [19].

The basic idea of the discriminant analysis problem is that we assume that the initial data can be classified correctly (i.e., in defining the groups) and some variables exist that permit the groups to be established. Unfortunately there is little theory to guide the selection of measurement variables.

A second fundamental requirement is a method of assessing or assigning group membership. One approach is based on the concept of generalized distance developed by Mahalanobis [23] in lieu of the concept of ordinary geometric (Euclidean) distance. The generalized distance is a measure of group or profile dissimilarity [33], i.e., the larger the generalized distance (23) the greater the dissimilarity between profiles.

Discriminant programs available at Texas A&M University are statistical packages within the Statistical Analysis System (SAS) [31]. The basic SAS discriminant procedures used in this study were stepwise discriminant (STEPDISC), canonical discriminant (CANDISC), and discriminant analysis (DISCRIM), respectively. The STEPDISC and CANDISC programs were used first to evaluate subsets of variables. The CANDISC, a

dimension reduction technique, is related to principal components and canonical correlation. The CANDISC procedure finds linear combination of the variables that best summarizes the differences among the classes. In addition, this procedure computes scores for each observation on the linear combination. The STEPDISC trys to find a subset of variables that best reveals differences among the classes. After a subset of variables is selected with the STEPDISC or CANDISC procedure, the discriminant procedure, DISCRIM, may be used to classify the observations into two or more known classes [31].

Stepwise Discriminant Analysis Program

The STEPDISC program performs the stepwise discriminant analysis which selects a subset of variables to form a discriminant model by forward selection, backward elimination, and stepwise selection. Variables are chosen on the basis of either criteria:

- The significance level of an F-test from an analysis of covariance, or
- The squared partial correlation for predicting the variable under consideration from the class variable.

The stepwise selection begins with no variable in the model. The variable that contributes the most to the discriminatory power of the model as measured by Wilks' lambda criterion is entered first. After all variables of the model have been tested by the criterion for entry into the model, the stepwise selection stops. Stepwise discriminant models are not necessarily the best possible models since Wilks' lambda may not be the best measure of discriminatory power. To guard against inclusion of variables that do not contribute to the discriminatory power of the model, it is customary to specify or select a minimum significance level.

Canonical Discriminant Analysis Program

The CANDISC analysis is a dimension-reduction technique related to principal component analysis and canonical correlation. The CANDISC program computes and tests Mahalanobis distances (23), performs univariate and multivariate analysis of variance, and derives a linear combination of variables, called the first canonical correlation, that has the highest possible multiple correlation within groups. The coefficients of the linear combination are the canonical coefficients. The variable defined by the linear combination is the first canonical variable. The second canonical correlation is obtained by finding the linear combination uncorrelated with the first canonical variable. The number of canonical variables equals the number of variables or the number of groups minus one, whichever is smaller. The output of the program includes the univariate statistics, covariance matrices, the Mahalanobis distances (23) between classes, multivariate statistics, the canonical coefficients, and plots of paired canonical variables. These plots are an aid to visual interpretation of group differences [31].

Discriminant Analysis Program

The DISCRIM program develops a discriminant model (classification criterion) by means of the generalized squared distance under the assumption that each class has a multivariate normal distribution. The generalized squared distance of observation vector X_i to group or class j is obtained from the equation:

$$D_j^2(X_i) = (X_i - X_j)' \; COV_j^{-1}(X_i - X_j) + Log_e|COV_j| \tag{23}$$

if the within-group covariance matrices, COV_j, are used X_j is the means of the variables in the group j. The criterion is based on either the individual within-group covariance matrices or the pooled covariance matrix. The DISCRIM program then computes linear or quadratic discriminant functions and places each observation (multivariate) into the class from which the distance is the smallest. The output of the program includes the within covariance matrices, within correlation coefficients, pooled covariance matrix, test of homogeneity of within covariance matrices, generalized squared distances, and a classification summary or confusion matrix. The tests of homogeneity determine whether the criterion is based on the within group covariance matrices of the pooled covariance matrix [31].

RESULTS AND DISCUSSION

This section presents the results of the discriminant analysis programs STEPDISC, CANDISC, and DISCRIM. The STEPDISC and CANDISC analysis were used to gain an insight as to which combination of variables would be most useful in revealing the differences among the classes. Then the linear discriminant analysis was used to classify: (1) a set of data, the "training set", and (2) a separate set of data not used in the training set, the "classification set" or the "test set".

STEPDISC Results

The stepwise linear discriminant analysis was performed on the expiratory portion of respiratory sound data for:(1) 4 classes with 4 variables, (2) 3 classes with 4 variables for each sound spectrum, and (3) 3 classes with mean values of the 4 variables from the average of 10 or more spectra for a subject. The 4 classes consisted of 2 abnormal groups and 2 normal groups. This analysis followed one of the possible cluster analysis groupings found by Lessard et al. [22]. The 3 class cases consisted of 2 abnormal groups and 1 normal group. Two class cases consisted of abnormal and normal groups. When 4 variables were used, flow rate was included. In all cases the 3 respiratory sound spectral variables (MPF, FPK, and FMAX) were used.

In the STEPDISC analysis of 4 classes with 4 variables, the first variable entered was the mean frequency of the respiratory spectrum (MPF) because of its high-squared correlation (R^2) value (Fig. 2). In the second step, the peak frequency (FPK) was entered (Fig. 2), and in the

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 3,258

VARIABLE	R**2	F	PROB > F	TOLERANCE
MPF	0.6963	197.182	0.0001	1.0000
FPK	0.1788	18.722	0.0001	1.0000
FMAX	0.5672	112.719	0.0001	1.0000
FLOW	0.0647	5.947	0.0007	1.0000

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.30369130	F(3,258) =	197.182	PROB > F =0.0000
PILLAI'S TRACE = 0.696309	F(3,258) =	197.182	PROB > F =0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.23210290

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 3,258

VARIABLE	R**2	F	PROB > F
MPF	0.6963	197.182	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 3,257

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.1450	14.527	0.0001	0.7277
FMAX	0.0644	5.897	0.0008	0.2806
FLOW	0.0312	2.760	0.0420	0.9652

VARIABLE FPK WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF FPK

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.25965893	F(6,514) =	82.450	PROB > F =0.0000
PILLAI'S TRACE = 0.806752	F(6,516) =	58.144	PROB > F =0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.26891730

Figure 2. STEPDISC result of 4 classes with 4 variables; steps 1 and 2 for expiratory data.

third step, the flow rate was entered in lieu of the FMAX (Fig. 3). An examination of the stepwise selection summary indicates that the squared correlation value (R^2) of the flow variable is low and the significance level of the F test from an analysis of covariance is not low (0.0313), indicating that flow may not contribute a great amount to the discriminating power (Fig. 4).

When the same expiratory sound data is analyzed by the STEPDISC program for the 3 classes with the 4 variables, MPF is selected in the first step (Fig. 5) and FPK is selected in the second step (Fig. 5). Flow rate and FMAX were not selected because the significance levels of the F test were high (Fig. 6), if a third variable were used the FMAX would be selected. The stepwise selection summary is given in Figure 6.

In the last case, the means of the spectral variables and the mean flow for each subject were used as input data into the STEPDISC program instead of the variables from each quarter-second spectrum. Results for the 3 classes, 4 variable analysis with a mean data set (Appendix E) are given in Figures 7 through 9. The variables selected in order of discriminating power are the MPF, FPK, and FMAX, respectively. Flow was not selected as a discriminant variable as indicated in the selection summary (Fig. 9).

In the next series of runs, the classes were reduced to 2 groups (normal and abnormal) with 4 variables and 3 variables (flow rate excluded). In the STEPDISC run with 2 classes with 4 variables during expiration, all 4 variables were entered as shown in Figures 10 through 12. For this case, FPK has the least discriminant power (Fig. 12). In the case of 2 classes with 4 variables during inspiration, the MPF was entered in the first step (Fig. 13) followed by the FMAX (Fig. 13). The flow rate was included as a variable, but FPK was not (Fig. 14). Selection summary is given in Figure 15.

In the case of 2 classes, with 3 variables (flow rate excluded) during expiration, the variables FPK, FMAX, and MPF were selected respectively even though the MPF had a high squared correlation (R^2) value and a F test significance level of 0.0001 as is shown in the stepwise selection summary (Fig. 15). For inspiratory data, the variables MPF and FMAX were selected; and the FPK was not entered (Fig. 15).

Table 1 is a summary of respiratory sound variable discriminating power. We noted that the MPF is the variable with the most discriminating power for all expiration studies except the 2 classes, 4 variables case. For the inspiration studies, the FMAX bandwidth was the most discriminating variable. The second most discriminating variable during expiration is the FPK or mode of the spectrum. Flow does not appear to be a strong discriminating variable. This result is in agreement with results presented by Wong [34] in which he suggests that the frequency spectra of respiratory sounds are independent of respiratory flow rate if the flow rate is about or greater than normal respiratory flow rate of about 0.75 to 1.0 L/s.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 3,257

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.6838	185.271	0.0001
FPK	0.1450	14.527	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 3,256

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FMAX	0.0150	1.297	0.2752	0.1725
FLOW	0.0338	2.987	0.0313	0.7153

VARIABLE FLOW WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF FPK FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.25087637	F(9,623.187) =	52.974	PROB > F =0.0000
PILLAI'S TRACE =	0.822477	F(9,774) =	32.483	PROB > F =0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.27415892

STEPWISE SELECTION: STEP 4

STATISTICS FOR REMOVAL, DF = 3,256

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.6792	180.697	0.0001
FPK	0.1473	14.740	0.0001
FLOW	0.0338	2.987	0.0313

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 3,255

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FMAX	0.0148	1.275	0.2829	0.1721

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

Figure 3. STEPDISC result of 4 classes with 4 variables; steps 3 and 4 for expiratory data.

STEPWISE SELECTION: SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB > LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	MPF		1	0.6963	197.182	0.0001	0.30369130	0.0000	0.23210290
2	FPK		2	0.1450	14.527	0.0001	0.25965893	0.0000	0.26891730
3	FLOW		3	0.0338	2.987	0.0313	0.25087637	0.0000	0.27415892

Figure 4. STEPDISC result selection summary of 4 classes; with 4 variables for expiratory data.

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 2,259

VARIABLE	R**2	F	PROB > F	TOLERANCE
MPF	0.5544	161.147	0.0001	1.0000
FPK	0.0876	12.438	0.0001	1.0000
FMAX	0.4775	118.329	0.0001	1.0000
FLOW	0.0272	3.622	0.0281	1.0000

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.44555783	F(2,259) =	161.147	PROB > F =0.0000
PILLAI'S TRACE =	0.554442	F(2,259) =	161.147	PROB > F =0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.27722108

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 2,259

VARIABLE	R**2	F	PROB > F
MPF	0.5544	161.147	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2,258

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.1450	21.874	0.0001	0.7277
FMAX	0.0636	8.769	0.0002	0.2806
FLOW	0.0016	0.203	0.8164	0.9652

VARIABLE FPK WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF FPK

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.38095991	F(4,516) =	80.002	PROB > F =0.0000
PILLAI'S TRACE =	0.649629	F(4,518) =	62.299	PROB > F =0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.32481441

Figure 5. STEPDISC result of 3 classes with 4 variables; steps 1 and 2 for expiratory data.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 2,258

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.5825	179.946	0.0001
FPK	0.1450	21.874	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2,257

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FMAX	0.0141	1.839	0.1611	0.1725
FLOW	0.0040	0.516	0.5978	0.7153

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

STEPWISE SELECTION: SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB > LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	MPF		1	0.5544	161.147	0.0001	0.44555783	0.0000	0.27722108
2	FPK		2	0.1450	21.874	0.0001	0.38095991	0.0000	0.32481441

Figure 6. STEPDISC result of 3 classes with 4 variables; step 3 and the selection summary for expiratory data.

```
                    STEPWISE SELECTION:  STEP   1

                    STATISTICS FOR ENTRY, DF = 2,8

        VARIABLE      R**2          F       PROB > F   TOLERANCE

        MMPF         0.7379      11.259     0.0047      1.0000
        MFPK         0.2681       1.465     0.2869      1.0000
        MFMAX        0.7378      11.253     0.0047      1.0000
        MFLOW        0.0452       0.189     0.8311      1.0000

                    VARIABLE MMPF WILL BE ENTERED

               THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
                                MMPF

                       MULTIVARIATE STATISTICS

WILKS' LAMBDA  = 0.26214565     F(2,8) =          11.259       PROB > F =0.0047
PILLAI'S TRACE =   0.737854     F(2,8) =          11.259       PROB > F =0.0047

           AVERAGE SQUARED CANONICAL CORRELATION = 0.36892718
-------------------------------------------------------------------------------
                    STEPWISE SELECTION:  STEP   2

                  STATISTICS FOR REMOVAL,  DF = 2,8

             VARIABLE      R**2         F      PROB > F

             MMPF         0.7379      11.259    0.0047

                    NO VARIABLES CAN BE REMOVED

                    ---------------------------

                    STATISTICS FOR ENTRY, DF = 2,7

                    PARTIAL
        VARIABLE      R**2          F       PROB > F   TOLERANCE

        MFPK         0.6482       6.449     0.0258      0.5064
        MFMAX        0.1970       0.858     0.4640      0.1689
        MFLOW        0.0044       0.015     0.9848      0.9563

                    VARIABLE MFPK WILL BE ENTERED

               THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
                              MMPF   MFPK

                       MULTIVARIATE STATISTICS

WILKS' LAMBDA  = 0.09222430     F(4,14) =          8.025       PROB > F [illegible]
PILLAI'S TRACE =   1.094258     F(4,16) =          4.833       PROB > F [illegible]

           AVERAGE SQUARED CANONICAL CORRELATION = 0.54712884
```

Figure 7. STEPDISC result of 3 classes with 4 variables; steps 1 and 2 for mean expiratory data.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 2,7

VARIABLE	PARTIAL R**2	F	PROB > F
MMPF	0.8740	24.275	0.0007
MFPK	0.6482	6.449	0.0258

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2,6

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
MFMAX	0.4831	2.803	0.1381	0.0315
MFLOW	0.0159	0.049	0.9530	0.4979

VARIABLE MFMAX WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED
MMPF MFPK MFMAX

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.04767531	F(6,12) =	7.160	PROB > F =0.0020
PILLAI'S TRACE =	1.166006	F(6,14) =	3.262	PROB > F =0.0320

AVERAGE SQUARED CANONICAL CORRELATION = 0.58300295

Figure 8. STEPDISC result of 3 classes with 4 variables; step 3 for mean expiratory data.

STEPWISE SELECTION: STEP 4

STATISTICS FOR REMOVAL, DF = 2,6

VARIABLE	PARTIAL R**2	F	PROB > F
MMPF	0.7721	10.164	0.0118
MFPK	0.7735	10.247	0.0116
MFMAX	0.4831	2.803	0.1381

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2,5

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
MFLOW	0.0136	0.035	0.9663	0.0285

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

STEPWISE SELECTION: SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB < LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	MMPF		1	0.7379	11.259	0.0047	0.26214565	0.0047	0.368927[illegible]8
2	MFPK		2	0.6482	6.449	0.0258	0.09222430	0.0014	0.5[illegible]12884
3	MFMAX		3	0.4831	2.803	0.1381	0.04767531	0.0020	0.58300295

Figure 9. STEPDISC result of 3 classes with 4 variables; step 4 and the selection summary for mean expiratory data.

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 1, 642

VARIABLE	R**2	F	PROB > F	TOLERANCE
MPF	0.0166	10.840	0.0010	1.0000
FPK	0.0226	14.875	0.0001	1.0000
FMAX	0.0080	5.177	0.0232	1.0000
FLOW	0.0533	36.117	0.0001	1.0000

VARIABLE FLOW WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.94673959	F(1,642) = 36.117	PROB > F = 0.0001
PILLAI'S TRACE =	0.053260	F(1,642) = 36.117	PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.05326041

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 1, 642

VARIABLE	R**2	F	PROB > F
FLOW	0.0533	36.117	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 641

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
MPF	0.0211	13.815	0.0002	0.9972
FPK	0.0205	13.445	0.0003	0.9977
FMAX	0.0055	3.557	0.0598	0.9943

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.92676581	F(2,641) = 25.326	PROB > F = 0.0001
PILLAI'S TRACE =	0.073234	F(2,641) = 25.326	PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.07323419

Figure 10. STEPDISC result of 2 classes with 4 variables; steps 1 and 2 for each expiration.

STEPWISE SELECTION STEP 3

STATISTICS FOR REMOVAL, DF = 1, 641

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.0211	13.815	0.0002
FLOW	0.0576	39.168	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 640

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.0085	5.518	0.0191	0.8268
FMAX	0.0678	46.517	0.0001	0.4793

VARIABLE FMAX WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED
MPF FMAX FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.86397018 F(3,640) = 33.589 PROB > F = 0.0001
PILLAI'S TRACE = 0.136030 F(3,640) = 33.589 PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.13602982

STEPWISE SELECTION STEP 4

STATISTICS FOR REMOVAL, DF = 1, 640

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.0824	57.443	0.0001
FMAX	0.0678	46.517	0.0001
FLOW	0.0550	37.253	0.0001

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 639

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.0042	2.706	0.1004	0.4140

VARIABLE FPK WILL BE ENTERED

ALL VARIABLES HAVE BEEN ENTERED

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.86032625 F(4,639) = 25.935 PROB > F = 0.0001
PILLAI'S TRACE = 0.139674 F(4,639) = 25.935 PROB > F = 0.0001

Figure 11. STEPDISC result of 2 classes with 4 variables; steps 3 and 4 for each expiration.

STEPWISE SELECTION STEP 5

STATISTICS FOR REMOVAL, DF = 1, 639

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0 0608	41 352	0 0001
FPK	0 0042	2 706	0 1001
FMAX	0 0637	43 463	0 0001
FLOW	0 0530	35 746	0 0001

NO VARIABLES CAN BE REMOVED

NO FURTHER STEPS ARE POSSIBLE

STEPWISE SELECTION SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB < LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	FLOW		1	0 0533	36 117	0 0001	0 94673959	0 0001	0 05326041
2	MPF		2	0 0211	13 815	0 0002	0 92676581	0 0001	0 07323419
3	FMAX		3	0 0678	46 517	0 0001	0 86397018	0 0001	0 13602982
4	FPK		4	0 0042	2 706	0 1001	0 86032625	0 0001	0 13967375

Figure 12. STEPDISC result of 2 classes with 4 variables; step 5 and the selection summary for each expiration.

STEPWISE SELECTION STEP 1

STATISTICS FOR ENTRY, DF = 1, 559

VARIABLE	R**2	F	PROB > F	TOLERANCE
MPF	0.0158	8.979	0.0029	1.0000
FPK	0.0142	8.047	0.0047	1.0000
FMAX	0.0001	0.081	0.7761	1.0000
FLOW	0.0121	6.875	0.0090	1.0000

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.98419152	F(1,559) = 8.979	PROB > F = 0.0029
PILLAI'S TRACE =	0.015808	F(1,559) = 8.979	PROB > F = 0.0029

AVERAGE SQUARED CANONICAL CORRELATION = 0.01580848

STEPWISE SELECTION STEP 2

STATISTICS FOR REMOVAL, DF = 1, 559

VARIABLE	R**2	F	PROB > F
MPF	0.0158	8.979	0.0029

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 558

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.0033	1.873	0.1717	0.6709
FMAX	0.0215	12.235	0.0005	0.3668
FLOW	0.0158	8.959	0.0029	0.9881

VARIABLE FMAX WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED
MPF FMAX

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.96307548	F(2,558) = 10.697	PROB > F = 0.0001
PILLAI'S TRACE =	0.036925	F(2,558) = 10.697	PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.03692452

Figure 13. STEPDISC result of 2 classes with 4 variables; steps 1 and 2 for each inspiration.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 1, 558

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.0368	21.310	0.0001
FMAX	0.0215	12.235	0.0005

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 557

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.0006	0.354	0.5521	0.2642
FLOW	0.0134	7.586	0.0061	0.3646

VARIABLE FLOW WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:
MPF FMAX FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA =	0.95013546	F(3,557) = 9.744	PROB > F = 0.0001
PILLAI'S TRACE =	0.049865	F(3,557) = 9.744	PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.04986454

STEPWISE SELECTION: STEP 4

STATISTICS FOR REMOVAL, DF = 1, 557

VARIABLE	PARTIAL R**2	F	PROB > F
MPF	0.0375	21.682	0.0001
FMAX	0.0191	10.847	0.0011
FLOW	0.0134	7.586	0.0061

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 556

VARIABLE	PARTIAL R**2	F	PROB > F	TOLERANCE
FPK	0.0010	0.536	0.4646	0.2641

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

Figure 14. STEPDISC result of 2 classes with 4 variables; steps 3 and 4 for each inspiration.

STEPWISE SELECTION SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB < LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	MPF		1	0.0158	8.979	0.0029	0.98419152	0.0029	0.01580848
2	FMAX		2	0.0215	12.235	0.0005	0.96307548	0.0001	0.03692452
3	FLOW		3	0.0134	7.586	0.0061	0.95013546	0.0001	0.04986454

STEPWISE SELECTION SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB < LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	FPK		1	0.0226	14.875	0.0001	0.97735543	0.0001	0.02264457
2	FMAX		2	0.0161	10.509	0.0012	0.96159031	0.0001	0.03840969
3	MPF		3	0.0553	37.435	0.0001	0.90845296	0.0001	0.09154704

STEPWISE SELECTION SUMMARY

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	F STATISTIC	PROB > F	WILKS' LAMBDA	PROB < LAMBDA	AVERAGE SQUARED CANONICAL CORRELATION
1	MPF		1	0.0158	8.979	0.0029	0.98419152	0.0029	0.01580848
2	FMAX		2	0.0215	12.235	0.0005	0.96307548	0.0001	0.03692452

Figure 15. Stepwise selection summaries:
(a) The selection summary for 2 classes with 4 variables during each inspiration, (b) the selection summary for 2 classes with 3 variables during each expiration, and (c) the selection summary for 2 classes with 3 variables during each inspiration.

Table 1. SUMMARY OF RANK ORDER OF VARIABLE DISCRIMINATING POWER

Resp. mode	Number classes	No. var.	Data set	Order 1	2	3	4	Ref Fig. No.
Exp	4	4	Each	MPF	FPK	FLOW		2-4
Exp	3	4	Each	MPF	FPK			5-6
Exp	3	4	Mean	MPF	FPK	FMAX		7-9
Exp	2	4	Each	FMAX	FLOW	MPF	FPK	10-12
Ins	2	4	Each	FMAX	MPF	FLOW		13-15
Exp	2	3	Each	MPF	FPK	FMAX		15
Ins	2	3	Each	FMAX	MPF			15

Exp = expiratory
Ins = inspiratory

CANDISC Results

The canonical discriminant program was initially run on the expiratory sound data with 4 classes and 4 variables. The means of the variables for a subject were used as input data to the CANDISC program. Table 2 shows the resulting Mahalanobis distances (23) between classes 0-3. There is less separation between abnormal class 0 and normal class 1, than between the 2 normal classes 1 and 3. Abnormal class 2 has the greatest separation from all other classes. This separation may also be readily seen in the plot of canonical variables CAN1 vs. CAN3 (Fig. 16).

Table 2. MAHALANOBIS DISTANCE BETWEEN CLASSES

Class	0	1	2	3
0	.	3.58	16.02	2.92
1	3.58	.	13.24	6.10
2	16.02	13.24	.	18.88
3	2.92	6.10	18.88	.

Note:
Normal: classes 1 & 3
Abnormal: classes 0 & 2

Table 3 is a summary of Mahalanobis distances (23) between classes for the 2 class cases (normal vs. abnormal). The table also shows that the distance between groups increases when the variables were averaged and were the greatest when the average flow was added as a fourth variable. This result appears to disagree with results from the stepwise linear analysis which did not include flow as a strong discriminant variable (except one case during inspiration - Fig. 15).

DISCRIM Results

Before running the discriminant analysis program (DISCRIM), the data was divided into 2 subsets, a "training" (contains 7 abnormals and 5 normals) set and an independent "test" set for classification with the discriminants obtained from the training set (Appendix A, direct set). In addition, the data was analyzed with the sets reversed, i.e., the training set became the independent test set and the test set was used as the

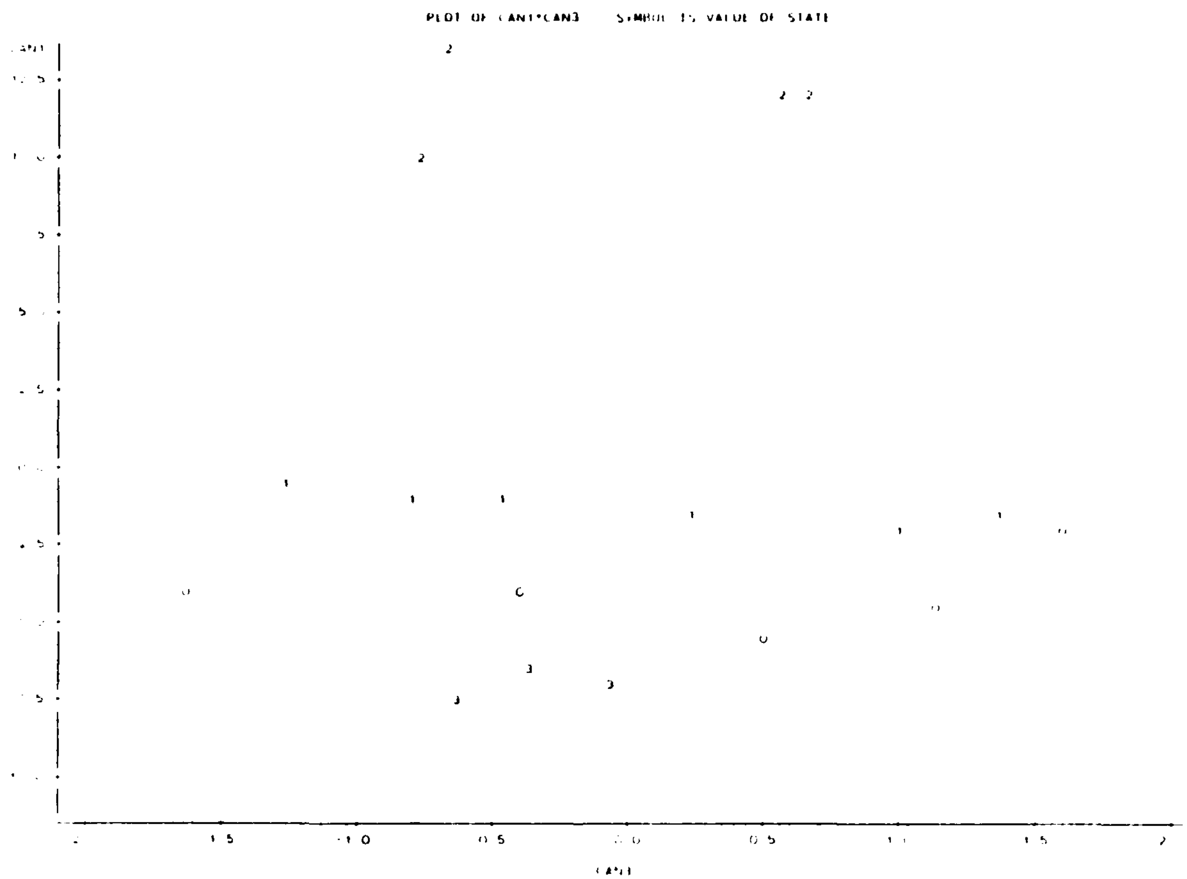

Figure 16. Plot of canonical variables CAN1 vs. CAN3 from CANDISC program results on mean expiratory data with 4 classes and 4 variables.

Table 3. SUMMARY OF MAHALANOBIS DISTANCES BETWEEN CLASSES FOR 2 CLASSES (NORMAL AND ABNORMAL)

	Expiration		Inspiration	
	Each	Mean	Each	Mean
4 variables	-	2.0899	-	1.3738
3 variables	0.6481	1.4475	0.3963	0.5310

training set. Runs with this data set are referred to as "reversed". As before, the data is in individual (1/4-s epoch) spectral variables or in averaged variables form. The terminology "each" is used when discussing data derived from the individual spectrum, and "mean" when discussing data derived from the average variables from numerous segments of breaths measured from a subject. Classification summaries of training and classification test data sets were obtained for "each" expiration (Appendix A), and inspiration (Appendix B) direct and reversed data sets.

For 2 classes (normal and abnormal), 3 parameters from each spectrum of expiration (Appendix A, Direct data set), Table 4 presents the classification summaries for the training and the classification sets. The number of correctly classified expiratory breaths from the training set are contained in the main diagonal, e.g., 170 and 89 = 259 correctly classified out of 348 or about 74.4%; off diagonal values are classification errors. For the training set, 54 abnormal expirations were misclassified as normal, and 35 normal expirations were misclassified as abnormal for a total of 89 out of 348 or 25.6% error.

Classification of the expiratory data reversed resulted in the summary Table 5. Approximately 40% of the training set is misclassified; this error increases to about 60% for new data (the classification test set).

Results of the discriminant analysis of "each" inspiratory sounds with direct and reversed data sets are presented in Tables 6 and 7. In both cases the training sets have fewer misclassified data points than the classification test set. Discriminant results are a little better with the direct data set than with reversed data set.

In addition, classification summaries were obtained from "mean" data sets given in Appendixes C and D. Tables 8 and 9 present the

Table 4. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, DIRECT DATA SET: EACH

Training Set

Number of observations classified into class:

Class	0	1	Total
0	170	54	224
1	35	89	124
Total	205	143	348

Misclassified 25.6%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	97	68	165
1	76	55	131
Total	173	123	296

Misclassified 48.6%

Class 0 = Abnormal, Class 1 = Normal.

Table 5. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, REVERSED DATA SET: EACH

Training Set

Number of observations classified into class:

Class	0	1	Total
0	56	109	165
1	9	122	131
Total	65	231	296

Misclassified 39.9%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	61	163	224
1	45	79	124
Total	106	242	348

Misclassified 59.8%

Class 0 = Abnormal, Class 1 = Normal.

Table 6. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, DIRECT DATA SET: EACH

Training Set

Number of observations classified into class:

Class	0	1	Total
0	151	30	181
1	48	86	134
Total	199	116	315

Misclassified 24.8%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	44	84	128
1	49	69	118
Total	93	153	246

Misclassified 54.1%

Class 0 = Abnormal, Class 1 = Normal.

Table 7. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, REVERSED DATA SET: EACH

Training Set

Class	Number of observations classified into class: 0	1	Total
0	51	77	128
1	10	108	118
Total	61	185	246

Misclassified 35.4%

Classification Set

Class	Number of observations classified into class: 0	1	Total
0	48	133	181
1	54	80	134
Total	102	213	315

Misclassified 59.4%

Class 0 = Abnormal, Class 1 = Normal.

classification summaries for expiratory sounds with direct and reversed data sets (Appendix C). The results of classifying new data are about the same with either data set. The overall classification accuracy is about 80%. Classification summaries for inspiratory sounds with direct and reversal data sets (Appendixes D) are given in Tables 10 and 11. In both cases, the accuracy for the training sets are better than classification accuracy for the test sets. The overall classification accuracy is about 67% with the direct and about 80% with the reversed data set.

To compare results obtained with the respiratory sound parameters to a standard pulmonary classification scheme, 3 pulmonary function test parameters provided by U.S. Air Force medical center were used to classify the subjects. The pulmonary function test parameters used as input variables to the discriminant analysis program were forced vital capacity (FVC), forced expiratory volume at 1 s (FEV1), and the ratio of forced expiratory volume at 1 s to forced vital capacity expressed in percentage (FEV1P). This data should correspond to classification with the mean data set since the pulmonary function test is per subject rather than per breath. The results of using the pulmonary function test parameters with direct and reversed data sets, Appendix E, are given in Tables 12 and 13. Note the similarity in results with the "mean" expiratory data (Tables 8 and 9) and the PFT results (Tables 12 and 13). This similarity may be explained by the fact that the pulmonary function test is per subject as is the mean of several breaths, and that the pulmonary function test is based primarily on measurements during forced expiration. There was an overall 20.8% error in classifying patients by the 3 parameters from the pulmonary function tests. The error may be caused by the classes, as seen by the standard 3 parameters, not being mutually exclusive, the data may be incorrectly classified, or not enough standard variables provided for evaluation.

Table 14 is a summary of all the discriminant classification runs. The upper half of the table presents percentage correctly classified and the lower half presents the total percent error in classification. As indicated by this table, classification with the mean data resulted in improved accuracy. The improved accuracy may be the result of better estimators due to smoothing of variability by averaging.

Regression Analysis

Multiple regression analysis was performed to determine if the spectral parameters for discriminating breath sounds correlate with the clinical data obtained by the pulmonary function test. In general, regression analysis fits least-square estimates to a linear regression model of the form:

$$y_i = W_0 + W_1 X1_i + W_2 X2_i + \dots + \epsilon_i \qquad (24)$$

where y_i is the dependent variable that can be predicted by a linear combination of the weighted independent variables X's for the observations $i = 1, 2, \dots, n$. The principle of least squares is used to produce estimates for the weighting factors (W's) that are the best linear

Table 8. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, DIRECT DATA SET: MEAN

Training Set

Number of observations classified into class:

Class	0	1	Total
0	7	0	7
1	1	4	5
Total	8	4	12

Misclassified 8.3%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	5	2	7
1	2	3	5
Total	7	5	12

Misclassified 33.3%

Class 0 = Abnormal, Class 1 = Normal.

Table 9. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, REVERSED DATA SET: MEAN

Training Set

Number of observations classified into class:

Class	0	1	Total
0	5	2	7
1	0	5	5
Total	5	7	12

Misclassified 16.7%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	4	3	7
1	0	5	5
Total	4	8	12

Misclassified 25%

Class 0 = Abnormal, Class 1 = Normal.

Table 10. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, DIRECT DATA SET: MEAN

Training Set

Class	0	1	Total
	Number of observations classified into class:		
0	6	1	7
1	0	5	5
Total	6	6	12

Misclassified 8.3%

Classification Set

Class	0	1	Total
	Number of observations classified into class:		
0	1	6	7
1	1	4	5
Total	2	10	12

Misclassified 58.3%

Class 0 = Abnormal, Class 1 = Normal.

Table 11. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, REVERSED DATA SET: MEAN

Training Set

Number of observations classified into class:

Class	0	1	Total
0	7	0	7
1	0	5	5
Total	7	5	12

Misclassified 0.0%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	7	0	7
1	5	0	5
Total	12	0	12

Misclassified 41.7%

Class 0 = Abnormal, Class 1 = Normal.

Table 12. CLASSIFICATION SUMMARY OF PFT, DIRECT DATA SET

Training Set

Number of observations classified into class:

Class	0	1	Total
0	7	0	7
1	0	5	5
Total	7	5	12

Misclassified 0.0%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	7	0	7
1	5	0	5
Total	12	0	12

Misclassified 41.7%

Class 0 = Abnormal, Class 1 = Normal.

Table 13. CLASSIFICATION SUMMARY OF PFT, REVERSED DATA SET

Training Set

Number of observations classified into class:

Class	0	1	Total
0	6	1	7
1	0	5	5
Total	6	6	12

Misclassified 8.3%

Classification Set

Number of observations classified into class:

Class	0	1	Total
0	7	0	7
1	4	1	5
Total	11	1	12

Misclassified 33.3%

Class 0 = Abnormal, Class 1 = Normal.

Table 14. SUMMARY OF CLASSIFICATION ACCURACY

Data Set Type	Direct Train	Direct Test	Direct Overall	Reversed Train	Reversed Test	Reversed Overall
Overall Percentage Correctly Classified						
Each expiration	77.4	51.4	63.8	60.1	40.2	49.4
Each inspiration	75.2	45.9	62.4	64.6	40.6	51.2
Mean expiration	91.7	66.7	79.2	83.3	75.0	79.2
Mean inspiration	91.7	41.7	66.7	100.0	58.3	79.2
PFT	100.0	58.3	79.2	91.7	66.7	79.2
Overall Percentage Misclassified						
Each expiration	25.6	48.6	36.2	39.9	59.8	50.6
Each inspiration	24.8	54.1	37.6	35.4	59.4	48.8
Mean expiration	8.3	33.3	20.8	16.7	25.0	20.8
Mean inspiration	8.3	58.3	33.3	0.0	41.7	20.8
PFT	0.0	41.7	20.8	8.3	33.3	20.8

unbiased estimates under classical statistical assumptions. The regression programs available at Texas A&M University are statistical packages within the SAS [31]. The program outputs a summary of the statistics for each dependent variable to each independent variable or combination of independent variables and plots of each dependent variable vs. each independent variable. Typical plots of a first order model for FVC as the dependent variable and the mean frequency of the spectral parameter (MPF) are given for expiration and inspiration in Figures 17 and 18 respectively. In both cases, the predicted linear fit are almost horizontal lines indicating that there is almost no relationship between the dependent and independent variables. This linear fit is backed up by the low R-square values which are 0.0025 and 0.0140. Table 15 summarizes the R-square values for the dependent variables and the independent variables used in the regression model. Expiratory data set used for the regression analysis is given in Appendix F and the inspiratory data set in Appendix G. In all cases the low values of R-square results indicates that this is minimal correlation or relationship between the 3 respiratory sound parameters and the 3 pulmonary function test parameters. Thus, pulmonary function test parameters (i.e., FVC or FEV1 or FEV1P) cannot be predicted by any combination of respiratory sound parameters (MPF, FPK, FMAX).

CONCLUSIONS

The objectives of this study were to determine whether respiratory sound data of normal volunteers and pulmonary insufficient subjects can be classified by DISCRIM analysis, and to determine if the spectral parameters for discriminating respiratory sounds correlate with the clinical parameters obtained from the pulmonary function test. Three DISCRIM analysis programs and a regression analysis package were used in the study.

The conclusions from the DISCRIM analysis are:

- Variables with the most discriminating power are MPF, FPK, and FMAX. Flow was not a good discriminator.
- Results of the CANDISC program indicated that the Mahalanobis distances (23) between the 2 classes (normal and abnormal) increase when variables were averaged (i.e., mean data set).
- Classification with the mean data is better than classification with data based on each breath. This data may be expected since the mean data set consist of estimators that have been smoothed by averaging thus reducing the variability. The only caution with accepting results from the mean data is the low number of samples in both normal and abnormal classes (12 each).
- Classification with the pulmonary function test parameters indicates that the classes may not have been classified 100% correctly by the rater or raters. This error in classification affects the outcome and accuracy of the discriminant program.
- Overall PFT direct rendered 19/24 = 79.2% correct and 5/24 = 20.8% error which is the same as mean expiration data direct (19/24 = 79.2% overall correct). In addition the reverse PFT rendered 19/24 = 79.2% correct and 5/24 = 20.8% error whereas mean expiration

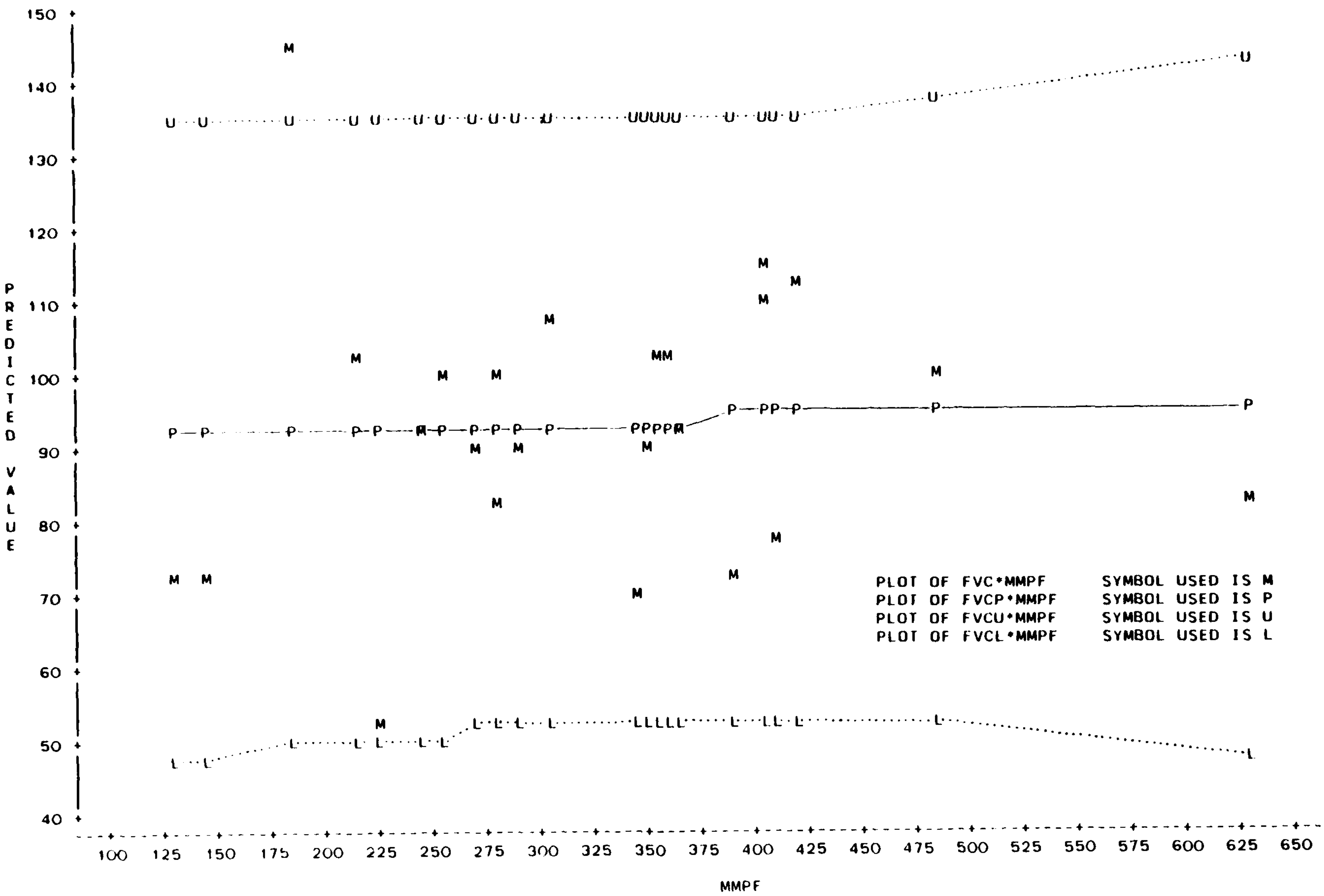

Figure 17. Regression analysis plot of first order model for FVC vs. MPF during expiration.

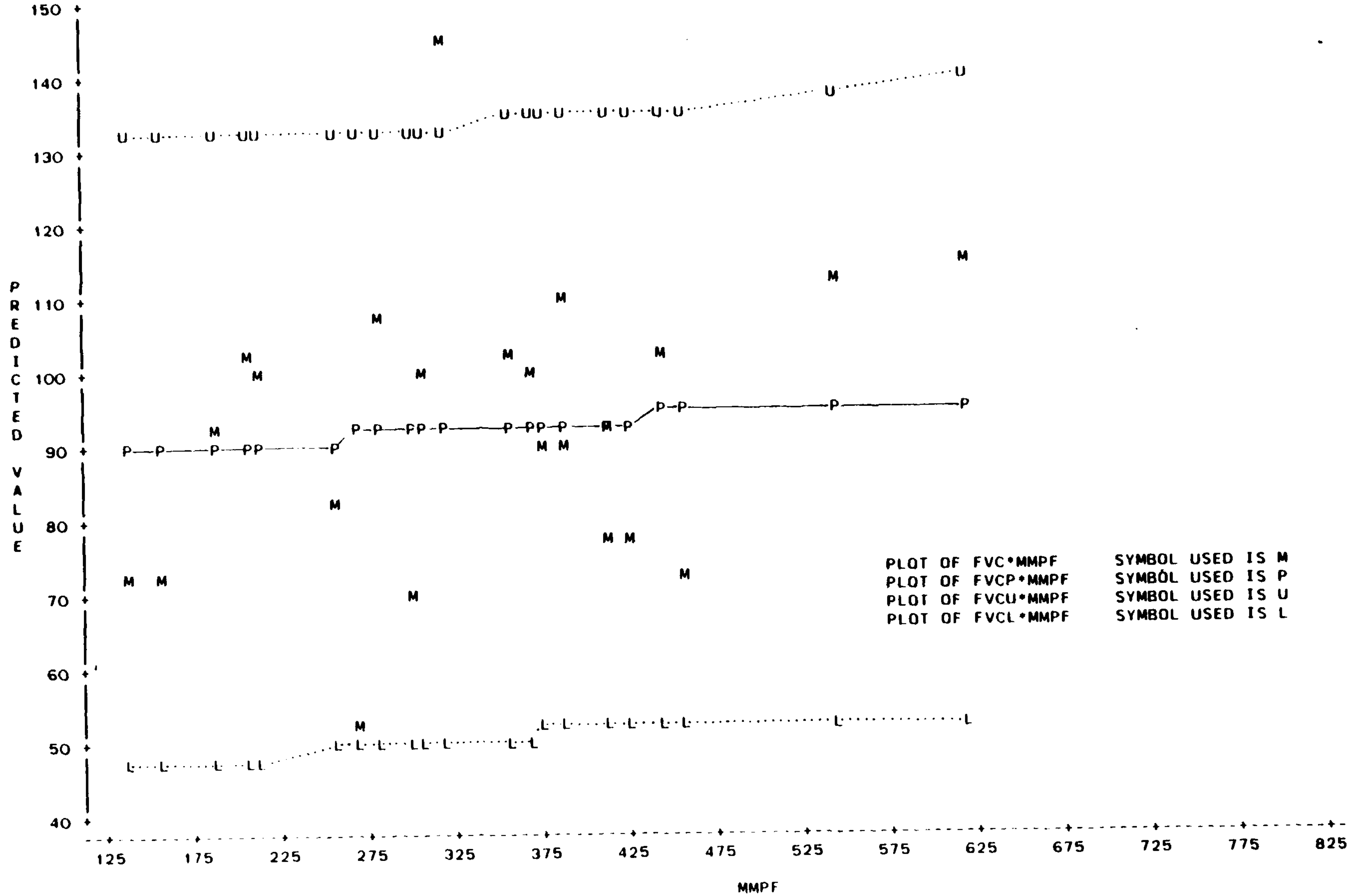

Figure 18. Regression analysis plot of first order model for FVC vs. MPF during inspiration.

Table 15. SUMMARY OF R-SQUARE VALUES OF REGRESSION MODELS

Mean data: Expiration, N = 24

No. of ind. var. in model	Independent variables	FVC	FEV1	FEV1P
1	MPF	0.0025	0.0107	0.0091
1	FPK	0.0166	0.0449	0.0073
1	FMAX	0.0070	0.0132	0.1063
2	MPF,FPK	0.0168	0.0450	0.0310
2	FPK,FMAX	0.0359	0.0863	0.1527
2	MPF,FMAX	0.0621	0.1638	0.2303
3	MPF,FPK,FMAX	0.0712	0.1853	0.2405

Mean data: Inspiration, N = 24

No. of ind. var. in model	Independent variables	FVC	FEV1	FEV1P
1	MPF	0.0140	0.0082	0.0214
1	FPK	0.0014	0.0034	0.0025
1	FMAX	0.0108	0.0008	0.0712
2	MPF,FPK	0.0201	0.0085	0.0298
2	FPK,FMAX	0.0120	0.0035	0.0930
2	MPF,FMAX	0.0147	0.0410	0.1859
3	MPF,FPK,FMAX	0.0250	0.0531	0.1968

reversed set also rendered 19/24 = 79.2% correct and 5/24 = 20.8% error.

Thus, results of classification with expiratory data approximates results of classification with the PFT variables. This stands to reason since the pulmonary function test is based on forced expiration measurements.

Conclusions from the regression studies are:

- The respiratory sound variable, peak frequency or mode of the spectrum (FPK) contributes the least to multiple regression.
- There is minimal or no correlation between the respiratory sound spectral parameters (MPF, FPK, FMAX) and the 3 pulmonary function test parameters (FVC, FEV1, FEV1P).

RECOMMENDATIONS

The results of the DISCRIM analysis are encouraging from the standpoint that classification with mean expiratory data closely approximates results from classification with the 3 pulmonary function test variables. Much has been learned from these studies -- for example, (1)better controls are needed during collection of data to reduce the variability; (2) since cardiac valve sounds may be heard with the respiration, the contribution of the valve sounds must be examined and eliminated, or reduced to decrease variability; and (3) other parameters from the respiratory spectra must be added and evaluated.

Each subject should be screened with a full pulmonary function test. These results should be classified by at least 3 experts in pulmonary function. Disagreements should not be used in the initial evaluation. Records and data in which full agreement is reached initially should only be used. The raters should be interviewed to establish which parameters and in what order were the parameters used in classification. Twelve or more subjects are necessary per class. To start, the classes should be mutually exclusive. Finally, the expansion of parameters should also include expansion of respiratory sound parameters, i.e., the spectral energy in broad frequency bands (100-150, 150-200, etc), the second and third movements of the distribution about zero. In short, we recommended that the study be repeated under contractor control from start to finish as soon as possible.

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APPENDIX A

EXPIRATION DIRECT DATA SET: EACH

Calibration or Training Set

7 Abnormals (STATE=0)

P
Q
T
U
X
+
#

5 Normals (STATE=1)

H
I
V
W
*

```
DATA EXP;
TITLE 'POWER SPECTRA DATA ON EXPIRATORY SOUND';
COMMENT STATE: NORMAL= 1  ABNORMAL= 0;
COMMENT DIRECT CALIBRATION DATA;
INPUT ID S FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;
CARDS;
    P    73   32   44   0     1.14       247.6       96.0     280.0
    P    73   32   44   0     1.57       275.6      104.0     248.0
    P    73   32   44   0     1.61       192.4       80.0     272.0
    P    73   32   44   0     1.51       229.5       80.0     260.0
    P    73   32   44   0     1.31       300.5      100.0     324.0
    P    73   32   44   0     1.30       180.6      108.0     260.0
    P    73   32   44   0     1.13       154.1       80.0     172.0
    P    73   32   44   0     1.11       352.9       64.0     260.0
    P    73   32   44   0     1.05       236.4       60.0     172.0
    P    73   32   44   0     1.0        365.4       108.0    264.0
    P    73   32   44   0     1.17       436.5       172.0    260.0
    P    73   32   44   0     1.79       341.7       128.0    1016.0
    P    73   32   44   0     1.97       367.9       172.0    620.0
    P    73   32   44   0     1.91       351.6       148.0    592.0
    P    73   32   44   0     1.74       365.4       96.0     1316.0
    P    73   32   44   0     1.54       286.6       108.0    560.0
    P    73   32   44   0     1.31       312.0       104.0    580.0
    P    73   32   44   0     1.16       450.3       172.0    1376.0
    P    73   32   44   0     1.03       367.6       100.0    420.0
    P    73   32   44   0     0.95       336.5       172.0    600.0
    P    73   32   44   0     0.68       484.6       172.0    1164.0
    P    73   32   44   0     1.21       527.1       172.0    1376.0
    P    73   32   44   0     1.54       514.9       160.0    1416.0
    P    73   32   44   0     1.60       625.3       156.0    1376.0
    P    73   32   44   0     1.64       475.8       208.0    1360.0
    P    73   32   44   0     1.57       383.5       148.0    612.0
    P    73   32   44   0     1.40       397.5       172.0    1256.0
    P    73   32   44   0     1.32       459.0       160.0    1332.0
    P    73   32   44   0     1.12       490.7       172.0    1288.0
    P    73   32   44   0     1.08       439.7       172.0    1336.0
    P    73   32   44   0     0.65       581.9       172.0    1276.0
    P    73   32   44   0     1.44       554.5       180.0    1440.0
    P    73   32   44   0     1.88       604.6       120.0    1388.0
    P    73   32   44   0     1.72       478.9       196.0    1372.0
    P    73   32   44   0     1.57       364.1       108.0    532.0
    P    73   32   44   0     1.42       271.9       100.0    636.0
    P    73   32   44   0     1.34       473.0       172.0    1452.0
    P    73   32   44   0     1.21       436.6       172.0    1360.0
    P    73   32   44   0     1.10       379.1       80.0     1056.0
    P    73   32   44   0     1.05       565.2       292.0    1372.0
    +    72   58  124   0     1.12       140.2       92.0     120.0
    +    72   58  124   0     1.37       90.4        92.0     112.0
    +    72   58  124   0     1.23       241.7       100.0    140.0
    +    72   58  124   0     1.19       186.1       80.0     124.0
    +    72   58  124   0     1.29       152.6       112.0    180.0
    +    72   58  124   0     1.08       209.7       108.0    148.0
```

+	72	58	124	0	0.80	190.6	72.0	140.0
+	72	58	124	0	0.78	129.3	72.0	180.0
+	72	58	124	0	0.62	116.4	64.0	128.0
+	72	58	124	0	0.99	121.2	108.0	188.0
+	72	58	124	0	1.46	133.1	88.0	128.0
+	72	58	124	0	1.52	135.6	104.0	188.0
+	72	58	124	0	1.35	138.4	120.0	164.0
+	72	58	124	0	1.38	114.4	104.0	152.0
+	72	58	124	0	1.23	133.0	88.0	192.0
+	72	58	124	0	0.84	124.6	112.0	156.0
+	72	58	124	0	0.92	127.7	88.0	148.0
+	72	58	124	0	1.55	110.4	96.0	136.0
+	72	58	124	0	1.42	113.4	96.0	140.0
+	72	58	124	0	1.65	132.6	96.0	164.0
+	72	58	124	0	1.74	112.4	96.0	172.0
+	72	58	124	0	1.31	103.0	104.0	120.0
+	72	58	124	0	1.03	144.9	104.0	144.0
+	72	58	124	0	0.91	123.1	68.0	176.0
+	72	58	124	0	0.64	106.4	80.0	112.0
+	72	58	124	0	0.71	144.4	88.0	136.0
+	72	58	124	0	0.85	110.2	84.0	132.0
+	72	58	124	0	0.90	109.5	84.0	144.0
+	72	58	124	0	0.94	109.5	92.0	144.0
+	72	58	124	0	1.01	103.9	104.0	160.0
+	72	58	124	0	1.07	120.6	112.0	160.0
+	72	58	124	0	1.11	118.5	96.0	168.0
+	72	58	124	0	1.04	117.8	84.0	140.0
*	99	105	105	1	0.69	431.7	112.0	260.0
*	99	105	105	1	1.06	413.2	112.0	124.0
*	99	105	105	1	1.22	592.8	260.0	1408.0
*	99	105	105	1	1.22	431.0	112.0	260.0
*	99	105	105	1	1.14	473.2	108.0	484.0
*	99	105	105	1	1.14	373.5	112.0	172.0
*	99	105	105	1	1.13	534.5	112.0	1316.0
*	99	105	105	1	1.15	519.9	112.0	260.0
*	99	105	105	1	1.18	531.5	112.0	1036.0
*	99	105	105	1	1.29	603.6	108.0	1476.0
*	99	105	105	1	1.29	394.7	112.0	124.0
*	99	105	105	1	1.28	476.2	112.0	776.0
*	99	105	105	1	1.26	478.9	112.0	560.0
*	99	105	105	1	1.20	471.8	112.0	1280.0
*	99	105	105	1	1.18	342.4	108.0	260.0
*	99	105	105	1	1.04	536.3	260.0	1376.0
*	99	105	105	1	1.27	459.5	108.0	256.0
*	99	105	105	1	1.24	562.2	108.0	1312.0
*	99	105	105	1	1.27	535.5	112.0	1332.0
*	99	105	105	1	1.21	543.2	172.0	1372.0
*	99	105	105	1	1.15	560.3	172.0	1344.0
*	99	105	105	1	1.08	389.9	108.0	260.0
*	99	105	105	1	1.07	538.4	172.0	512.0
*	99	105	105	1	0.75	575.6	108.0	1280.0
*	99	105	105	1	1.05	523.8	112.0	260.0

*	99	105	105	1	1.05	484.6	172.0	1316.0
*	99	105	105	1	1.08	361.0	112.0	172.0
*	99	105	105	1	1.13	419.3	108.0	172.0
*	99	105	105	1	1.16	463.6	112.0	260.0
*	99	105	105	1	1.07	524.8	112.0	500.0
#	70	74	106	0	0.46	386.5	116.0	1372.0
#	70	74	106	0	0.64	414.9	112.0	588.0
#	70	74	106	0	0.71	404.2	176.0	652.0
#	70	74	106	0	0.80	400.1	92.0	632.0
#	70	74	106	0	0.89	378.8	156.0	724.0
#	70	74	106	0	0.95	401.1	132.0	672.0
#	70	74	106	0	0.92	391.3	144.0	1180.0
#	70	74	106	0	0.98	170.1	80.0	152.0
#	70	74	106	0	0.97	291.1	116.0	260.0
#	70	74	106	0	0.59	188.0	72.0	260.0
#	70	74	106	0	0.74	127.6	84.0	172.0
#	70	74	106	0	0.92	244.9	152.0	568.0
#	70	74	106	0	0.97	202.7	92.0	260.0
#	70	74	106	0	0.99	219.4	148.0	572.0
#	70	74	106	0	0.96	254.2	92.0	568.0
#	70	74	106	0	0.88	286.4	136.0	604.0
#	70	74	106	0	0.84	249.1	72.0	556.0
#	70	74	106	0	0.94	163.5	124.0	168.0
#	70	74	106	0	0.70	417.1	112.0	640.0
#	70	74	106	0	0.92	289.0	116.0	372.0
#	70	74	106	0	1.05	368.5	116.0	596.0
#	70	74	106	0	1.22	451.9	116.0	676.0
#	70	74	106	0	1.20	438.5	108.0	652.0
#	70	74	106	0	1.18	497.3	556.0	676.0
#	70	74	106	0	1.02	459.5	576.0	644.0
#	70	74	106	0	0.97	465.0	88.0	1136.0
#	70	74	106	0	1.14	357.5	112.0	568.0
#	70	74	106	0	0.27	361.7	108.0	260.0
#	70	74	106	0	0.38	360.9	92.0	1144.0
#	70	74	106	0	0.68	451.5	108.0	676.0
#	70	74	106	0	0.85	414.2	100.0	1352.0
#	70	74	106	0	1.05	435.2	108.0	1144.0
#	70	74	106	0	1.27	359.3	148.0	568.0
#	70	74	106	0	1.19	402.4	144.0	632.0
#	70	74	106	0	1.13	417.8	492.0	1148.0
#	70	74	106	0	1.08	388.0	112.0	632.0
Q	102	83	81	0	1.10	279.3	80.0	600.0
Q	102	83	81	0	1.70	417.0	600.0	608.0
Q	102	83	81	0	1.65	337.0	584.0	616.0
Q	102	83	81	0	1.40	246.2	92.0	600.0
Q	102	83	81	0	1.10	142.2	88.0	600.0
Q	102	83	81	0	0.82	217.7	96.0	600.0
Q	102	83	81	0	0.60	146.9	116.0	600.0
Q	102	83	81	0	0.43	95.2	64.0	600.0
Q	102	83	81	0	0.23	131.0	124.0	600.0
Q	102	83	81	0	1.03	147.8	68.0	600.0
Q	102	83	81	0	1.53	288.4	600.0	600.0

Q	102	83	81	0	1.63	306.3	92.0	612.0
Q	102	83	81	0	1.39	195.7	80.0	604.0
Q	102	83	81	0	1.11	249.5	96.0	608.0
Q	102	83	81	0	0.84	107.0	76.0	104.0
Q	102	83	81	0	0.61	244.1	84.0	600.0
Q	102	83	81	0	0.41	148.4	112.0	600.0
Q	102	83	81	0	0.33	97.5	60.0	108.0
Q	102	83	81	0	1.01	161.5	84.0	600.0
Q	102	83	81	0	1.69	319.7	88.0	620.0
Q	102	83	81	0	1.79	315.3	96.0	612.0
Q	102	83	81	0	1.52	177.3	72.0	604.0
Q	102	83	81	0	1.16	217.4	92.0	600.0
Q	102	83	81	0	0.91	118.0	64.0	164.0
Q	102	83	81	0	0.68	281.1	600.0	600.0
Q	102	83	81	0	0.48	171.9	128.0	600.0
Q	102	83	81	0	0.32	101.1	72.0	600.0
Q	102	83	81	0	0.77	112.9	64.0	132.0
Q	102	83	81	0	1.52	311.3	104.0	628.0
Q	102	83	81	0	1.65	272.1	76.0	612.0
Q	102	83	81	0	1.57	350.1	204.0	616.0
Q	102	83	81	0	1.32	273.9	92.0	604.0
Q	102	83	81	0	1.06	153.8	108.0	600.0
Q	102	83	81	0	0.73	249.1	88.0	600.0
Q	102	83	81	0	0.49	190.1	600.0	600.0
Q	102	83	81	0	0.36	98.0	64.0	600.0
X	93	78	85	0	1.11	290.3	160.0	732.0
X	93	78	85	0	1.34	356.5	196.0	772.0
X	93	78	85	0	1.05	272.3	120.0	624.0
X	93	78	85	0	0.92	323.5	96.0	688.0
X	93	78	85	0	0.79	268.1	156.0	636.0
X	93	78	85	0	0.57	328.5	188.0	648.0
X	93	78	85	0	1.00	240.0	104.0	604.0
X	93	78	85	0	0.88	262.1	116.0	560.0
X	93	78	85	0	0.78	199.0	96.0	180.0
X	93	78	85	0	0.61	174.6	80.0	120.0
X	93	78	85	0	0.87	235.5	136.0	600.0
X	93	78	85	0	0.78	230.5	108.0	260.0
X	93	78	85	0	0.74	222.9	96.0	416.0
X	93	78	85	0	0.65	141.0	112.0	164.0
X	93	78	85	0	0.52	206.0	100.0	260.0
X	93	78	85	0	0.41	277.2	104.0	448.0
X	93	78	85	0	0.85	248.5	112.0	520.0
X	93	78	85	0	0.89	217.2	100.0	496.0
X	93	78	85	0	0.83	271.2	88.0	596.0
X	93	78	85	0	0.72	182.6	96.0	172.0
V	101	106	104	1	1.11	132.2	88.0	144.0
V	101	106	104	1	1.73	208.8	108.0	396.0
V	101	106	104	1	1.74	203.8	116.0	180.0
V	101	106	104	1	1.57	206.1	104.0	160.0
V	101	106	104	1	1.42	223.9	96.0	348.0
V	101	106	104	1	1.27	146.7	100.0	144.0
V	101	106	104	1	1.06	162.8	112.0	160.0

V	101	106	104	1	0.87	150.2	104.0	164.0
V	101	106	104	1	1.51	434.6	628.0	648.0
V	101	106	104	1	1.61	336.6	628.0	644.0
V	101	106	104	1	1.43	343.6	620.0	636.0
V	101	106	104	1	1.23	387.7	628.0	632.0
V	101	106	104	1	1.03	298.0	620.0	640.0
V	101	106	104	1	0.83	237.9	116.0	628.0
V	101	106	104	1	1.92	353.9	104.0	740.0
V	101	106	104	1	2.07	362.8	120.0	636.0
V	101	106	104	1	1.35	328.1	116.0	636.0
V	101	106	104	1	0.95	283.4	116.0	636.0
V	101	106	104	1	0.66	225.5	104.0	628.0
V	101	106	104	1	1.66	426.3	620.0	640.0
V	101	106	104	1	1.61	396.7	616.0	628.0
V	101	106	104	1	1.04	369.1	620.0	628.0
V	101	106	104	1	0.69	271.8	616.0	624.0
V	101	106	104	1	0.51	238.4	108.0	624.0
W	107	114	106	1	0.26	343.3	108.0	260.0
W	107	114	106	1	0.41	300.1	112.0	260.0
W	107	114	106	1	0.48	352.4	108.0	260.0
W	107	114	106	1	0.46	341.7	128.0	520.0
W	107	114	106	1	0.37	295.5	108.0	260.0
W	107	114	106	1	0.29	313.5	112.0	260.0
W	107	114	106	1	0.63	475.7	260.0	1404
W	107	114	106	1	0.55	430.0	180.0	1212.0
W	107	114	106	1	0.78	395.1	260.0	1056.0
W	107	114	106	1	0.78	231.6	124.0	288.0
W	107	114	106	1	0.56	348.2	176.0	528.0
W	107	114	106	1	0.35	148.9	84.0	192.0
W	107	114	106	1	0.53	211.3	124.0	320.0
W	107	114	106	1	0.49	205.4	120.0	260.0
W	107	114	106	1	0.49	270.6	172.0	384.0
W	107	114	106	1	0.43	381.6	172.0	388.0
W	107	114	106	1	0.34	323.4	84.0	260.0
W	107	114	106	1	0.34	244.8	148.0	348.0
W	107	114	106	1	0.54	250.4	88.0	600.0
W	107	114	106	1	0.55	297.9	140.0	632.0
W	107	114	106	1	0.47	232.4	116.0	364.0
W	107	114	106	1	0.36	288.8	108.0	628.0
T	83	76	91	0	0.64	225.1	104.0	560.0
T	83	76	91	0	0.99	127.3	96.0	120.0
T	83	76	91	0	1.12	389.4	588.0	616.0
T	83	76	91	0	1.30	402.6	584.0	612.0
T	83	76	91	0	1.26	158.4	92.0	588.0
T	83	76	91	0	1.05	413.6	588.0	608.0
T	83	76	91	0	1.05	241.0	80.0	588.0
T	83	76	91	0	0.89	328.8	592.0	592.0
T	83	76	91	0	0.66	257.3	76.0	596.0
T	83	76	91	0	0.22	94.6	84.0	112.0
T	83	76	91	0	0.94	354.8	588.0	596.0
T	83	76	91	0	1.20	323.0	592.0	608.0
T	83	76	91	0	1.48	399.8	584.0	612.0

T	83	76	91	0	1.48	234.2	84.0	600.0
T	83	76	91	0	1.25	414.6	588.0	600.0
T	83	76	91	0	0.99	193.6	112.0	584.0
T	83	76	91	0	0.96	114.4	80.0	592.0
T	83	76	91	0	0.69	393.4	592.0	604.0
T	83	76	91	0	0.84	128.8	100.0	112.0
T	83	76	91	0	1.05	357.2	584.0	604.0
T	83	76	91	0	1.29	317.9	228.0	608.0
T	83	76	91	0	1.38	155.4	88.0	456.0
T	83	76	91	0	1.34	364.3	584.0	616.0
T	83	76	91	0	1.08	235.7	92.0	592.0
T	83	76	91	0	0.83	368.1	592.0	608.0
T	83	76	91	0	0.67	318.9	76.0	600.0
T	83	76	91	0	0.28	121.5	76.0	148.0
T	83	76	91	0	0.85	390.3	592.0	592.0
T	83	76	91	0	1.12	360.3	584.0	592.0
T	83	76	91	0	1.32	305.8	124.0	600.0
T	83	76	91	0	1.26	379.4	584.0	596.0
T	83	76	91	0	1.15	249.2	96.0	596.0
T	83	76	91	0	1.08	198.9	116.0	588.0
T	83	76	91	0	1.02	397.2	588.0	600.0
T	83	76	91	0	0.95	253.2	100.0	592.0
T	83	76	91	0	0.54	165.5	100.0	592.0
U	73	66	90	0	0.91	156.0	96.0	260.0
U	73	66	90	0	0.88	222.3	172.0	560.0
U	73	66	90	0	1.06	234.4	84.0	260.0
U	73	66	90	0	1.29	129.7	108.0	148.0
U	73	66	90	0	1.32	156.5	88.0	260.0
U	73	66	90	0	0.91	262.0	96.0	520.0
U	73	66	90	0	0.68	114.7	104.0	172.0
U	73	66	90	0	0.96	118.4	92.0	100.0
U	73	66	90	0	1.01	158.3	72.0	260.0
U	73	66	90	0	1.03	137.5	100.0	160.0
U	73	66	90	0	0.99	114.2	80.0	124.0
U	73	66	90	0	0.89	102.9	80.0	172.0
U	73	66	90	0	0.90	102.1	96.0	136.0
U	73	66	90	0	0.99	115.1	92.0	132.0
U	73	66	90	0	0.99	134.2	104.0	172.0
U	73	66	90	0	0.99	96.9	96.0	112.0
U	73	66	90	0	1.07	115.0	96.0	168.0
U	73	66	90	0	0.39	173.9	116.0	260.0
U	73	66	90	0	0.97	131.5	80.0	260.0
U	73	66	90	0	1.24	173.3	96.0	260.0
U	73	66	90	0	1.37	106.4	68.0	128.0
U	73	66	90	0	1.27	112.8	80.0	120.0
U	73	66	90	0	0.90	169.0	96.0	260.0
H	114	110	96	1	.75	446.5	172.0	260.0
H	114	110	96	1	.85	452.7	108.0	260.0
H	114	110	96	1	.78	460.5	172.0	260.0
H	114	110	96	1	.63	364.5	112.0	260.0
H	114	110	96	1	.46	477.9	172.0	500.0
H	114	110	96	1	.35	444.0	112.0	776.0

H	114	110	96	1	.21	442.5	260.0	1360.0
H	114	110	96	1	.55	440.8	108.0	260.0
H	114	110	96	1	.60	482.0	124.0	1268.0
H	114	110	96	1	.67	338.1	172.0	256.0
H	114	110	96	1	.55	425.3	112.0	300.0
H	114	110	96	1	.41	439.4	108.0	260.0
H	114	110	96	1	.31	414.1	112.0	260.0
H	114	110	96	1	.39	466.2	172.0	260.0
H	114	110	96	1	.41	432.3	172.0	260.0
H	114	110	96	1	.41	415.7	112.0	260.0
H	114	110	96	1	.42	382.7	260.0	1400.0
H	114	110	96	1	.39	410.2	172.0	348.0
H	114	110	96	1	.52	316.9	172.0	260.0
H	114	110	96	1	.53	357.1	112.0	260.0
H	114	110	96	1	.59	429.2	172.0	260.0
H	114	110	96	1	.61	246.8	112.0	260.0
H	114	110	96	1	.61	367.8	172.0	260.0
H	114	110	96	1	.58	296.9	92.0	260.0
I	112	118	105	1	.78	429.8	636.0	744.0
I	112	118	105	1	.80	396.3	144.0	744.0
I	112	118	105	1	.67	421.8	608.0	624.0
I	112	118	105	1	.58	425.1	160.0	708.0
I	112	118	105	1	.55	433.7	604.0	672.0
I	112	118	105	1	.42	431.1	604.0	736.0
I	112	118	105	1	.86	441.9	192.0	776.0
I	112	118	105	1	.80	446.2	604.0	712.0
I	112	118	105	1	.70	452.9	608.0	692.0
I	112	118	105	1	.67	458.3	628.0	704.0
I	112	118	105	1	.61	445.0	608.0	668.0
I	112	118	105	1	.51	316.2	112.0	628.0
I	112	118	105	1	.29	397.1	112.0	772.0
I	112	118	105	1	.56	379.1	84.0	744.0
I	112	118	105	1	.61	431.9	612.0	708.0
I	112	118	105	1	.62	451.4	608.0	748.0
I	112	118	105	1	.52	488.7	612.0	664.0
I	112	118	105	1	.46	386.8	96.0	748.0
I	112	118	105	1	.73	345.6	112.0	776.0
I	112	118	105	1	.81	514.6	668.0	784.0
I	112	118	105	1	.76	486.9	664.0	788.0
I	112	118	105	1	.86	298.3	112.0	784.0
I	112	118	105	1	.77	378.0	124.0	728.0
I	112	118	105	1	.81	431.2	588.0	724.0

Expiration Direct Data Set: Each

Test Set

7 Abnormals (STATE=0)

M
C
D
G
S
B
E

5 Normals (STATE=1)

K
L
F
Y
N

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DATA EXP;
TITLE 'POWER SPECTRA DATA ON EXPIRATORY SOUND';
COMMENT STATE: NORMAL= 1  ABNORMAL= 0;
COMMENT DIRECT TEST DATA;
INPUT ID $ FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;
CARDS;
 B    82   70   85   0    .99     707.3  172.0   1480.0
 B    82   70   85   0   1.0      651.7  412.0   1476.0
 B    82   70   85   0    .90     799.8  152.0   1440.0
 B    82   70   85   0    .77     777.6  172.0   1468.0
 B    82   70   85   0    .65     723.7  172.0   1448.0
 B    82   70   85   0   1.12     665.0  572.0   1488.0
 B    82   70   85   0   1.18     603.4  172.0   1068.0
 B    82   70   85   0   1.12     636.0  172.0   1364.0
 B    82   70   85   0   0.93     634.7  116.0   1472.0
 B    82   70   85   0    .74     797.9  172.0   1404.0
 B    82   70   85   0    .62     756.8  108.0   1388.0
 B    82   70   85   0    .58     782.1  172.0   1456.0
 B    82   70   85   0    .71     730.7  172.0   1464.0
 B    82   70   85   0    .90     720.2  956.0   1048.0
 B    82   70   85   0   0.80     614.1  112.0   1044.0
 B    82   70   85   0    .63     648.7  112.0   1456.0
 B    82   70   85   0    .52     606.3  172.0   1300.0
 B    82   70   85   0    .46     661.4  108.0   1456.0
 B    82   70   85   0    .40     646.2  172.0   1404.0
 B    82   70   85   0    .90     489.3  596.0    980.0
 B    82   70   85   0    .80     479.1  620.0    680.0
 B    82   70   85   0    .74     443.5  584.0    636.0
 B    82   70   85   0    .62     454.6  288.0    700.0
 B    82   70   85   0    .52     427.1  592.0    688.0
 B    82   70   85   0    .44     278.9  112.0    604.0
 C   77   78   99   0    .64     323.9    332.0    604.0
 C   77   78   99   0   1.1      414.1    412.0    684.0
 C   77   78   99   0   1.03     396.0    452.0    616.0
 C   77   78   99   0    .83     429.5    436.0    624.0
 C   77   78   99   0    .63     311.4    124.0    620.0
 C   77   78   99   0    .65     354.5    468.0    612.0
 C   77   78   99   0    .83     440.0    592.0    620.0
 C   77   78   99   0    .97     441.5    472.0    632.0
 C   77   78   99   0    .86     464.2    464.0    632.0
 C   77   78   99   0    .70     384.8    460.0    620.0
 C   77   78   99   0    .68     328.6    592.0    616.0
 C   77   78   99   0   1.00     475.5    600.0    620.0
 C   77   78   99   0   1.00     476.9    600.0    624.0
 C   77   78   99   0   1.00     447.8    604.0    604.0
 C   77   78   99   0    .89     464.8    592.0    628.0
 C   77   78   99   0    .73     414.3    608.0    632.0
 C   77   78   99   0    .39     217.6     76.0    584.0
 C   77   78   99   0    .99     475.8    600.0    620.0
 C   77   78   99   0    .99     473.3    600.0    624.0
 C   77   78   99   0    .99     459.9    604.0    604.0
 C   77   78   99   0    .89     459.9    592.0    616.0
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C	77	78	99	0	.73	336.6	104.0	620.0
D	102	100	97	0	.44	443.3	240.0	1360.0
D	102	100	97	0	.48	457.8	284.0	432.0
D	102	100	97	0	.45	495.6	172.0	1196.0
D	102	100	97	0	.45	434.7	260.0	1264.0
D	102	100	97	0	.41	432.3	240.0	1252.0
D	102	100	97	0	.52	270.5	100.0	392.0
D	102	100	97	0	.52	385.3	272.0	1292.0
D	102	100	97	0	.48	400.3	244.0	1336.0
D	102	100	97	0	.43	363.1	172.0	760.0
D	102	100	97	0	.57	278.2	292.0	660.0
D	102	100	97	0	.57	259.8	172.0	596.0
D	102	100	97	0	.56	276.4	240.0	600.0
D	102	100	97	0	.50	236.2	172.0	600.0
D	102	100	97	0	.47	288.9	160.0	612.0
D	102	100	97	0	.48	328.4	228.0	708.0
D	102	100	97	0	.45	311.0	236.0	632.0
E	90	72	81	0	.34	257.9	68.0	564.0
E	90	72	81	0	.40	305.8	96.0	604.0
E	90	72	81	0	.38	345.9	596.0	612.0
E	90	72	81	0	.37	129.5	104.0	128.0
E	90	72	81	0	.35	162.1	104.0	148.0
E	90	72	81	0	.29	152.7	96.0	196.0
E	90	72	81	0	.30	305.4	96.0	720.0
E	90	72	81	0	.26	379.0	140.0	676.0
E	90	72	81	0	.28	473.2	676.0	692.0
E	90	72	81	0	.29	558.7	676.0	724.0
E	90	72	81	0	.29	194.8	100.0	144.0
E	90	72	81	0	.31	215.9	112.0	496.0
E	90	72	81	0	.35	206.4	108.0	536.0
E	90	72	81	0	.30	184.5	92.0	184.0
E	90	72	81	0	.41	262.7	104.0	612.0
E	90	72	81	0	.46	223.6	212.0	548.0
E	90	72	81	0	.55	319.2	204.0	608.0
E	90	72	81	0	.51	285.5	192.0	604.0
E	90	72	81	0	.48	331.3	196.0	616.0
E	90	72	81	0	.28	154.4	92.0	176.0
E	90	72	81	0	.43	296.4	108.0	608.0
E	90	72	81	0	.43	206.0	104.0	608.0
E	90	72	81	0	.50	286.4	184.0	624.0
E	90	72	81	0	.52	289.2	208.0	620.0
E	90	72	81	0	.52	271.2	204.0	604.0
E	90	72	81	0	.46	253.4	220.0	616.0
F	146	141	97	1	.47	150.0	100.0	168.0
F	146	141	97	1	.62	246.1	112.0	588.0
F	146	141	97	1	.53	211.2	100.0	576.0
F	146	141	97	1	.54	129.4	100.0	148.0
F	146	141	97	1	.56	197.2	92.0	200.0
F	146	141	97	1	.52	203.8	104.0	492.0
F	146	141	97	1	.48	135.4	112.0	196.0
F	146	141	97	1	.73	181.1	120.0	236.0
F	146	141	97	1	.73	210.4	176.0	248.0

F	146	141	97	1	.68	181.6	160.0	220.0
F	146	141	97	1	.66	180.8	164.0	240.0
F	146	141	97	1	.70	210.7	168.0	592.0
F	146	141	97	1	.75	189.8	156.0	444.0
F	146	141	97	1	.71	207.5	160.0	600.0
F	146	141	97	1	.58	149.9	88.0	456.0
F	146	141	97	1	.52	164.2	152.0	476.0
F	146	141	97	1	.45	192.2	100.0	284.0
F	146	141	97	1	.38	226.2	148.0	576.0
F	146	141	97	1	.31	216.6	176.0	604.0
F	146	141	97	1	.27	200.8	108.0	532.0
F	146	141	97	1	.31	238.5	116.0	632.0
F	146	141	97	1	.31	166.3	84.0	548.0
F	146	141	97	1	.41	145.6	80.0	184.0
F	146	141	97	1	.44	151.3	108.0	240.0
F	146	141	97	1	.58	156.4	100.0	180.0
F	146	141	97	1	.64	175.0	112.0	188.0
F	146	141	97	1	.63	189.0	128.0	176.0
F	146	141	97	1	.66	203.2	136.0	464.0
F	146	141	97	1	.43	173.0	92.0	172.0
F	146	141	97	1	.47	175.4	88.0	168.0
G	91	78	118	0	.63	180.8	132.0	264.0
G	91	78	118	0	.77	286.5	224.0	780.0
G	91	78	118	0	.87	249.5	176.0	696.0
G	91	78	118	0	.85	253.5	156.0	720.0
G	91	78	118	0	.77	201.3	84.0	252.0
G	91	78	118	0	.52	117.7	80.0	124.0
G	91	78	118	0	.89	324.4	204.0	608.0
G	91	78	118	0	1.05	338.3	216.0	788.0
G	91	78	118	0	.97	341.4	176.0	620.0
G	91	78	118	0	.74	356.9	212.0	668.0
G	91	78	118	0	.60	405.2	168.0	760.0
G	91	78	118	0	.45	318.7	108.0	720.0
G	91	78	118	0	.48	330.2	204.0	772.0
G	91	78	118	0	.69	330.9	200.0	768.0
G	91	78	118	0	.64	370.0	172.0	708.0
G	91	78	118	0	.50	370.4	168.0	752.0
G	91	78	118	0	.19	338.3	196.0	728.0
G	91	78	118	0	.19	320.6	188.0	716.0
G	91	78	118	0	.48	309.3	164.0	696.0
G	91	78	118	0	.69	190.7	108.0	176.0
G	91	78	118	0	.64	179.2	100.0	184.0
S	92	95	103	0	1.05	227.4	96.0	260.0
S	92	95	103	0	1.35	238.8	92.0	260.0
S	92	95	103	0	1.38	267.9	120.0	260.0
S	92	95	103	0	1.25	262.9	100.0	536.0
S	92	95	103	0	1.03	316.6	56.0	1328.0
S	92	95	103	0	0.83	593.5	120.0	1356.0
S	92	95	103	0	0.88	354.1	120.0	1340.0
S	92	95	103	0	0.88	129.6	100.0	168.0
S	92	95	103	0	1.14	516.1	92.0	976.0
S	92	95	103	0	1.04	329.7	76.0	772.0

S	92	95	103	0	0.86	221.3	112.0	496.0
S	92	95	103	0	0.80	543.7	600.0	952.0
S	92	95	103	0	0.74	284.8	80.0	776.0
S	92	95	103	0	0.61	202.3	120.0	260.0
S	92	95	103	0	1.17	361.8	120.0	260.0
S	92	95	103	0	1.58	291.7	120.0	604.0
S	92	95	103	0	1.68	360.3	108.0	760.0
S	92	95	103	0	1.58	423.3	580.0	836.0
S	92	95	103	0	1.49	400.2	120.0	660.0
S	92	95	103	0	1.25	351.5	120.0	260.0
S	92	95	103	0	0.80	384.7	120.0	260.0
S	92	95	103	0	1.68	695.6	120.0	1392.0
S	92	95	103	0	1.80	636.0	120.0	1428.0
S	92	95	103	0	1.50	581.1	120.0	260.0
S	92	95	103	0	1.22	362.8	120.0	612.0
S	92	95	103	0	1.00	266.2	120.0	260.0
S	92	95	103	0	0.94	292.6	88.0	260.0
Y	101	113	113	1	0.59	432.5	112.0	172.0
Y	101	113	113	1	0.70	442.8	112.0	236.0
Y	101	113	113	1	0.78	523.5	108.0	1348.0
Y	101	113	113	1	0.78	411.5	108.0	204.0
Y	101	113	113	1	0.74	402.5	112.0	228.0
Y	101	113	113	1	0.65	428.5	172.0	1364.0
Y	101	113	113	1	0.64	484.4	112.0	532.0
Y	101	113	113	1	0.58	381.1	108.0	176.0
Y	101	113	113	1	0.52	442.1	112.0	172.0
Y	101	113	113	1	1.15	170.6	100.0	268.0
Y	101	113	113	1	1.55	303.6	252.0	580.0
Y	101	113	113	1	1.32	184.5	88.0	380.0
Y	101	113	113	1	1.18	246.5	164.0	612.0
Y	101	113	113	1	1.01	136.0	104.0	156.0
Y	101	113	113	1	0.78	166.9	76.0	196.0
Y	101	113	113	1	0.63	130.2	116.0	144.0
Y	101	113	113	1	0.48	138.6	80.0	168.0
Y	101	113	113	1	1.28	171.0	96.0	152.0
Y	101	113	113	1	1.58	278.1	88.0	672.0
Y	101	113	113	1	1.47	202.5	92.0	504.0
Y	101	113	113	1	1.30	234.7	76.0	508.0
Y	101	113	113	1	1.19	166.4	88.0	244.0
Y	101	113	113	1	1.03	190.2	92.0	268.0
Y	101	113	113	1	0.89	143.5	120.0	168.0
Y	101	113	113	1	0.75	130.9	92.0	140.0
Y	101	113	113	1	1.34	305.2	88.0	736.0
Y	101	113	113	1	1.57	245.7	112.0	616.0
Y	101	113	113	1	1.28	229.2	160.0	328.0
Y	101	113	113	1	1.11	144.7	108.0	280.0
Y	101	113	113	1	0.95	171.3	88.0	260.0
Y	101	113	113	1	0.86	111.5	104.0	148.0
Y	101	113	113	1	0.74	107.6	84.0	160.0
Y	101	113	113	1	0.61	111.0	76.0	152.0
K	102	105	104	1	.47	331.5	188.0	608.0
K	102	105	104	1	.67	322.0	176.0	600.0

K	102	105	104	1	.71	365.2	496.0	608.0
K	102	105	104	1	.68	377.4	180.0	604.0
K	102	105	104	1	.55	288.9	172.0	600.0
K	102	105	104	1	.55	407.3	596.0	608.0
K	102	105	104	1	.62	363.6	588.0	616.0
K	102	105	104	1	.62	361.2	160.0	604.0
K	102	105	104	1	.52	319.8	596.0	612.0
K	102	105	104	1	.48	348.7	596.0	604.0
K	102	105	104	1	.58	412.0	476.0	596.0
K	102	105	104	1	.61	377.7	588.0	592.0
K	102	105	104	1	.58	379.6	588.0	612.0
K	102	105	104	1	.48	360.8	192.0	612.0
K	102	105	104	1	.30	354.1	472.0	616.0
K	102	105	104	1	.50	366.1	460.0	604.0
K	102	105	104	1	.51	350.8	168.0	604.0
K	102	105	104	1	.49	402.7	588.0	608.0
K	102	105	104	1	.48	409.1	592.0	600.0
K	102	105	104	1	.37	332.3	148.0	596.0
L	110	102	92	1	.72	366.3	464.0	592.0
L	110	102	92	1	.68	416.5	476.0	608.0
L	110	102	92	1	.63	421.8	524.0	600.0
L	110	102	92	1	.58	420.4	452.0	588.0
L	110	102	92	1	.62	440.6	500.0	604.0
L	110	102	92	1	.64	439.3	532.0	576.0
L	110	102	92	1	.64	410.6	468.0	612.0
L	110	102	92	1	.57	350.1	516.0	588.0
L	110	102	92	1	.56	439.6	516.0	572.0
L	110	102	92	1	.94	399.2	500.0	620.0
L	110	102	92	1	.90	376.8	488.0	596.0
L	110	102	92	1	.85	405.3	484.0	616.0
L	110	102	92	1	.79	400.9	492.0	624.0
L	110	102	92	1	.75	409.9	152.0	620.0
L	110	102	92	1	.74	385.3	496.0	560.0
L	110	102	92	1	.78	418.8	492.0	600.0
L	110	102	92	1	.83	403.3	484.0	612.0
L	110	102	92	1	.76	407.7	460.0	600.0
L	110	102	92	1	.71	401.9	476.0	580.0
L	110	102	92	1	.67	421.3	492.0	608.0
M	53	38	68	0	.86	144.6	88.0	600.0
M	53	38	68	0	.92	234.8	68.0	612.0
M	53	38	68	0	.94	216.5	108.0	604.0
M	53	38	68	0	.91	219.7	72.0	608.0
M	53	38	68	0	.87	290.7	92.0	604.0
M	53	38	68	0	.81	198.7	112.0	512.0
M	53	38	68	0	.74	214.5	96.0	432.0
M	53	38	68	0	.70	160.4	108.0	136.0
M	53	38	68	0	.76	173.3	80.0	596.0
M	53	38	68	0	.82	198.8	92.0	600.0
M	53	38	68	0	.81	165.2	72.0	116.0
M	53	38	68	0	.82	226.2	124.0	596.0
M	53	38	68	0	.84	193.8	72.0	604.0
M	53	38	68	0	.84	238.5	108.0	596.0

M	53	38	68	0	.74	212.8	104.0	600.0
M	53	38	68	0	.46	117.9	108.0	140.0
M	53	38	68	0	.86	228.0	88.0	604.0
M	53	38	68	0	.88	228.8	68.0	592.0
M	53	38	68	0	1.12	351.6	576.0	616.0
M	53	38	68	0	1.14	287.8	84.0	616.0
M	53	38	68	0	.97	336.0	464.0	608.0
M	53	38	68	0	.91	265.8	100.0	596.0
M	53	38	68	0	.82	171.2	92.0	140.0
M	53	38	68	0	.90	216.0	96.0	580.0
M	53	38	68	0	.86	279.3	88.0	596.0
M	53	38	68	0	.84	237.4	84.0	600.0
M	53	38	68	0	.81	277.6	100.0	612.0
M	53	38	68	0	.75	243.2	76.0	604.0
N	91	97	107	1	.39	325.1	172.0	608.0
N	91	97	107	1	.49	316.8	200.0	596.0
N	91	97	107	1	.54	306.7	212.0	616.0
N	91	97	107	1	.53	328.1	200.0	628.0
N	91	97	107	1	.50	382.6	596.0	612.0
N	91	97	107	1	.50	258.5	116.0	608.0
N	91	97	107	1	.50	354.4	596.0	616.0
N	91	97	107	1	.49	326.1	604.0	604.0
N	91	97	107	1	.44	348.7	172.0	612.0
N	91	97	107	1	.54	359.8	456.0	616.0
N	91	97	107	1	.57	340.9	132.0	620.0
N	91	97	107	1	.56	346.0	132.0	608.0
N	91	97	107	1	.50	391.0	488.0	596.0
N	91	97	107	1	.45	498.2	608.0	736.0
N	91	97	107	1	.56	339.2	280.0	616.0
N	91	97	107	1	.73	339.1	240.0	596.0
N	91	97	107	1	.76	351.5	312.0	604.0
N	91	97	107	1	.71	344.4	132.0	624.0
N	91	97	107	1	.70	352.5	264.0	680.0
N	91	97	107	1	.65	297.4	468.0	564.0
N	91	97	107	1	.59	316.4	120.0	596.0
N	91	97	107	1	.53	314.5	112.0	608.0
N	91	97	107	1	.60	393.8	456.0	580.0
N	91	97	107	1	.81	375.1	528.0	624.0
N	91	97	107	1	.37	392.7	492.0	612.0
N	91	97	107	1	.91	372.8	440.0	628.0
N	91	97	107	1	.93	373.1	416.0	636.0
N	91	97	107	1	.87	373.1	468.0	620.0

APPENDIX B

INSPIRATION DIRECT DATA SET: EACH

Calibration or Training Set

7 Abnormals (STATE=0)

P
Q
T
U
X
+
#

5 Normals (STATE=1)

H
I
V
W
*

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DATA BREATH:
TITLE 'POWER SPECTRA DATA ON INSPIRATORY SOUND';
COMMENT STATE: NORMAL= 1  ABNORMAL= 0;
COMMENT DIRECT CALIBRATION DATA;
INPUT ID S FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;
CARDS;
   P    73   32   44   0      1.28       255.5       84.0     280.0
   P    73   32   44   0      2.19       416.2       92.0     260.0
   P    73   32   44   0      2.29       539.4      172.0    1416.0
   P    73   32   44   0      2.47       822.6     1316.0    1448.0
   P    73   32   44   0      2.59       475.0      180.0    1348.0
   P    73   32   44   0      2.76       350.2      172.0    1404.0
   P    73   32   44   0      2.76       361.6      176.0     528.0
   P    73   32   44   0      1.65       505.5      172.0    1296.0
   P    73   32   44   0      2.40       407.9      152.0    1276.0
   P    73   32   44   0      2.55       427.7      172.0    1344.0
   P    73   32   44   0      2.64       442.9      168.0    1356.0
   P    73   32   44   0      2.64       301.0       96.0     260.0
   P    73   32   44   0      2.21       275.8      172.0     260.0
   P    73   32   44   0      1.17       749.0      116.0    1416.0
   P    73   32   44   0      2.15       775.1      180.0    1484.0
   P    73   32   44   0      2.54       334.0      172.0     408.0
   P    73   32   44   0      2.89       291.2      172.0     268.0
   P    73   32   44   0      2.98       314.9      172.0     240.0
   P    73   32   44   0      2.44       301.0      116.0     504.0
   P    73   32   44   0      1.64       380.2      104.0    1340.0
   P    73   32   44   0      2.03       585.7      172.0    1332.0
   P    73   32   44   0      2.33       547.1      172.0    1252.0
   P    73   32   44   0      2.52       434.5      164.0    1316.0
   P    73   32   44   0      2.61       633.2      164.0    1464.0
   P    73   32   44   0      2.48       452.0      156.0     624.0
   Q   102   83   81   0       .56      103.5       64.0    144.0
   Q   102   83   81   0      1.13      328.0      112.0    600.0
   Q   102   83   81   0      1.39      235.0       80.0    616.0
   Q   102   83   81   0      1.37      175.1       60.0    604.0
   Q   102   83   81   0      1.22      235.3      100.0    612.0
   Q   102   83   81   0      1.07      137.8       68.0    612.0
   Q   102   83   81   0       .99      276.4      112.0    604.0
   Q   102   83   81   0       .86      125.7      104.0    600.0
   Q   102   83   81   0       .71       94.5       68.0    600.0
   Q   102   83   81   0       .73      141.9      100.0    600.0
   Q   102   83   81   0      1.19      343.2      600.0    624.0
   Q   102   83   81   0      1.47      247.0       88.0    632.0
   Q   102   83   81   0      1.43      173.2       64.0    604.0
   Q   102   83   81   0      1.29      315.8      104.0    680.0
   Q   102   83   81   0      1.09      140.5       60.0    140.0
   Q   102   83   81   0      1.11      269.7       88.0    608.0
   Q   102   83   81   0      1.07      119.3       96.0    116.0
   Q   102   83   81   0       .68       99.5       84.0    600.0
   Q   102   83   81   0       .88      156.0      120.0    600.0
   Q   102   83   81   0      1.35      324.3      100.0    632.0
   Q   102   83   81   0      1.57      224.3      100.0    624.0
```

Q	102	83	81	0	1.60	220.6	64.0	628.0
Q	102	83	81	0	1.62	453.0	604.0	620.0
Q	102	83	81	0	1.43	161.9	92.0	608.0
Q	102	83	81	0	1.11	158.1	60.0	608.0
Q	102	83	81	0	.95	126.8	100.0	108.0
Q	102	83	81	0	.70	101.5	64.0	600.0
Q	102	83	81	0	.68	144.1	88.0	156.0
Q	102	83	81	0	1.31	229.0	56.0	620.0
Q	102	83	81	0	1.55	338.3	600.0	640.0
Q	102	83	81	0	1.70	197.3	100.0	620.0
Q	102	83	81	0	1.61	205.2	64.0	620.0
Q	102	83	81	0	1.58	376.7	608.0	608.0
Q	102	83	81	0	1.48	194.3	80.0	612.0
Q	102	83	81	0	1.14	199.7	116.0	624.0
Q	102	83	81	0	1.03	110.2	96.0	108.0
Q	102	83	81	0	.91	124.9	60.0	608.0
H	114	110	96	1	1.20	577.1	260.0	1372.0
H	114	110	96	1	1.10	569.9	260.0	1400.0
H	114	110	96	1	1.00	657.1	260.0	1472.0
H	114	110	96	1	.78	622.2	260.0	1228.0
H	114	110	96	1	.94	640.3	204.0	1348.0
H	114	110	96	1	0.91	541.0	196.0	1472.0
H	114	110	96	1	0.87	656.3	260.0	1268.0
H	114	110	96	1	0.86	618.9	172.0	1360.0
H	114	110	96	1	.86	686.1	260.0	1364.0
H	114	110	96	1	.79	689.2	260.0	1380.0
H	114	110	96	1	1.3	610.7	204.0	1340.0
H	114	110	96	1	1.2	604.8	260.0	1468.0
H	114	110	96	1	.90	685.1	260.0	1460.0
H	114	110	96	1	.70	673.0	260.0	1424.0
H	114	110	96	1	.94	623.9	172.0	1432.0
H	114	110	96	1	.93	555.0	172.0	1404.0
H	114	110	96	1	.87	620.0	172.0	1348.0
H	114	110	96	1	.77	513.1	172.0	260.0
T	83	76	91	0	.63	419.7	260.0	1224.0
T	83	76	91	0	.97	285.1	104.0	592.0
T	83	76	91	0	1.02	98.7	92.0	136.0
T	83	76	91	0	1.12	303.6	88.0	596.0
T	83	76	91	0	1.06	105.1	92.0	132.0
T	83	76	91	0	1.17	271.4	100.0	592.0
T	83	76	91	0	1.08	299.5	588.0	596.0
T	83	76	91	0	.96	100.4	92.0	124.0
T	83	76	91	0	.73	134.1	76.0	592.0
T	83	76	91	0	.98	403.1	592.0	604.0
T	83	76	91	0	1.09	147.2	104.0	592.0
T	83	76	91	0	1.18	347.1	592.0	600.0
T	83	76	91	0	1.20	179.5	96.0	588.0
T	83	76	91	0	1.15	122.6	100.0	144.0
T	83	76	91	0	1.08	357.4	588.0	592.0
T	83	76	91	0	.57	256.7	128.0	600.0
T	83	76	91	0	.82	164.7	128.0	208.0
T	83	76	91	0	.83	160.3	120.0	588.0

T	83	76	91	0	.94	415.8	584.0	600.0
T	83	76	91	0	.99	245.8	108.0	600.0
T	83	76	91	0	1.08	149.9	104.0	588.0
T	83	76	91	0	1.23	344.0	128.0	592.0
T	83	76	91	0	.88	308.5	116.0	600.0
T	83	76	91	0	.86	209.8	116.0	592.0
T	83	76	91	0	.96	347.3	96.0	600.0
T	83	76	91	0	1.05	193.3	112.0	584.0
T	83	76	91	0	1.09	413.4	240.0	1224.0
T	83	76	91	0	1.09	317.6	100.0	1224.0
T	83	76	91	0	1.052	170.0	108.0	584.0
T	83	76	91	0	1.09	399.2	252.0	608.0
T	83	76	91	0	.69	364.1	116.0	1224.0
U	73	66	90	0	.85	208.9	84.0	644.0
U	73	66	90	0	.90	350.3	88.0	1352.0
U	73	66	90	0	.80	160.6	100.0	172.0
U	73	66	90	0	.75	226.8	84.0	588.0
U	73	66	90	0	.36	225.2	100.0	260.0
U	73	66	90	0	.60	102.5	88.0	116.0
U	73	66	90	0	1.10	98.6	96.0	104.0
U	73	66	90	0	1.17	177.7	108.0	220.0
U	73	66	90	0	1.00	99.6	100.0	108.0
U	73	66	90	0	.88	146.4	52.0	260.0
U	73	66	90	0	.82	207.5	96.0	260.0
U	73	66	90	0	.96	100.7	96.0	140.0
U	73	66	90	0	.98	140.6	96.0	208.0
U	73	66	90	0	.98	190.0	88.0	260.0
U	73	66	90	0	.73	97.1	92.0	132.0
U	73	66	90	0	.31	123.2	96.0	204.0
U	73	66	90	0	.89	164.1	80.0	264.0
U	73	66	90	0	1.06	97.5	52.0	144.0
U	73	66	90	0	.98	115.3	88.0	124.0
U	73	66	90	0	.91	165.5	96.0	260.0
U	73	66	90	0	.81	93.8	96.0	116.0
U	73	66	90	0	.43	110.5	92.0	172.0
V	101	106	104	1	.90	206.6	76.0	604.0
V	101	106	104	1	1.32	240.5	100.0	612.0
V	101	106	104	1	1.56	303.0	100.0	620.0
V	101	106	104	1	1.70	266.3	124.0	628.0
V	101	106	104	1	1.63	300.1	100.0	624.0
V	101	106	104	1	1.46	392.6	600.0	652.0
V	101	106	104	1	1.20	214.3	96.0	620.0
V	101	106	104	1	.72	175.0	120.0	260.0
V	101	106	104	1	1.38	440.7	624.0	652.0
V	101	106	104	1	1.80	443.6	616.0	652.0
V	101	106	104	1	1.89	450.4	624.0	652.0
V	101	106	104	1	1.82	351.2	116.0	684.0
V	101	106	104	1	1.61	481.2	632.0	656.0
V	101	106	104	1	1.10	247.2	104.0	172.0
V	101	106	104	1	.80	162.8	132.0	156.0
V	101	106	104	1	1.46	197.4	140.0	284.0
V	101	106	104	1	2.06	315.0	104.0	692.0

V	101	106	104	1	2.35	315.2	156.0	656.0
V	101	106	104	1	2.18	262.3	104.0	176.0
V	101	106	104	1	1.70	228.5	92.0	668.0
V	101	106	104	1	.70	157.1	104.0	208.0
V	101	106	104	1	.97	272.4	88.0	632.0
V	101	106	104	1	1.77	494.9	628.0	640.0
V	101	106	104	1	2.17	433.5	644.0	644.0
V	101	106	104	1	2.08	366.9	628.0	676.0
V	101	106	104	1	1.60	295.6	112.0	684.0
V	101	106	104	1	.62	170.2	120.0	184.0
W	107	114	106	1	.78	395.2	260.0	548.0
W	107	114	106	1	1.23	358.0	112.0	552.0
W	107	114	106	1	1.10	453.4	128.0	348.0
W	107	114	106	1	1.01	242.5	136.0	412.0
W	107	114	106	1	.80	295.6	104.0	404.0
W	107	114	106	1	.56	154.5	76.0	260.0
W	107	114	106	1	.52	415.0	124.0	304.0
W	107	114	106	1	.88	392.3	128.0	536.0
W	107	114	106	1	.97	331.7	104.0	588.0
W	107	114	106	1	.91	270.0	152.0	600.0
W	107	114	106	1	.65	257.5	140.0	284.0
W	107	114	106	1	.73	338.1	96.0	660.0
W	107	114	106	1	.94	288.4	100.0	592.0
W	107	114	106	1	1.04	289.7	124.0	400.0
W	107	114	106	1	.92	196.7	124.0	328.0
W	107	114	106	1	.66	199.5	156.0	204.0
W	107	114	106	1	.79	134.9	124.0	172.0
W	107	114	106	1	1.10	211.8	124.0	380.0
W	107	114	106	1	1.18	229.6	112.0	328.0
W	107	114	106	1	1.11	243.0	132.0	616.0
W	107	114	106	1	.94	183.0	84.0	384.0
X	93	78	85	0	.73	146.7	116.0	164.0
X	93	78	85	0	.98	219.1	104.0	200.0
X	93	78	85	0	.93	157.8	104.0	156.0
X	93	78	85	0	.97	181.3	92.0	208.0
X	93	78	85	0	.59	124.5	96.0	164.0
X	93	78	85	0	.84	148.7	104.0	172.0
X	93	78	85	0	1.01	221.9	136.0	288.0
X	93	78	85	0	.96	203.6	100.0	152.0
X	93	78	85	0	.85	148.4	64.0	172.0
X	93	78	85	0	.77	246.6	108.0	260.0
X	93	78	85	0	.53	365.8	132.0	568.0
X	93	78	85	0	.67	139.5	88.0	260.0
X	93	78	85	0	1.01	238.0	108.0	492.0
X	93	78	85	0	1.03	184.5	84.0	260.0
X	93	78	85	0	.95	287.5	116.0	356.0
X	93	78	85	0	.84	283.6	104.0	468.0
X	93	78	85	0	.72	175.7	108.0	172.0
X	93	78	85	0	.33	120.1	80.0	136.0
X	93	78	85	0	.87	229.1	108.0	260.0
X	93	78	85	0	1.48	237.9	164.0	492.0
X	93	78	85	0	1.41	140.2	120.0	200.0

X	93	78	85	0	1.42	140.1	104.0	172.0
X	93	78	85	0	1.32	141.7	116.0	136.0
X	93	78	85	0	.96	131.6	108.0	192.0
X	93	78	85	0	.52	105.5	84.0	168.0
I	112	118	105	1	1.06	533.6	584.0	768.0
I	112	118	105	1	1.26	478.0	616.0	768.0
I	112	118	105	1	1.34	518.1	588.0	740.0
I	112	118	105	1	1.31	521.9	608.0	716.0
I	112	118	105	1	1.48	486.6	632.0	788.0
I	112	118	105	1	1.57	509.1	448.0	780.0
I	112	118	105	1	1.59	467.5	452.0	752.0
I	112	118	105	1	1.67	474.6	680.0	740.0
I	112	118	105	1	1.30	465.9	600.0	780.0
I	112	118	105	1	1.70	489.1	456.0	780.0
I	112	118	105	1	1.66	482.4	592.0	632.0
I	112	118	105	1	1.71	441.6	476.0	788.0
I	112	118	105	1	1.83	471.0	456.0	780.0
I	112	118	105	1	1.90	496.9	536.0	760.0
I	112	118	105	1	.64	565.9	808.0	1328.0
I	112	118	105	1	1.02	619.3	172.0	1260.0
I	112	118	105	1	1.24	664.8	256.0	1400.0
I	112	118	105	1	1.44	653.7	780.0	1136.0
I	112	118	105	1	1.34	689.7	228.0	1444.0
I	112	118	105	1	1.32	705.2	288.0	1448.0
I	112	118	105	1	1.18	695.3	260.0	1392.0
I	112	118	105	1	1.15	828.8	1364.0	1476.0
I	112	118	105	1	.99	757.1	260.0	1484.0
I	112	118	105	1	1.70	458.2	456.0	776.0
I	112	118	105	1	2.2	368.3	152.0	776.0
I	112	118	105	1	2.3	477.1	492.0	772.0
I	112	118	105	1	2.4	442.9	508.0	780.0
I	112	118	105	1	2.42	439.4	472.0	1460.0
I	112	118	105	1	2.17	517.1	300.0	1464.0
+	72	58	124	0	1.54	141.5	108.0	152.0
+	72	58	124	0	1.80	170.4	104.0	148.0
+	72	58	124	0	1.71	168.8	80.0	204.0
+	72	58	124	0	1.35	196.3	68.0	132.0
+	72	58	124	0	1.04	128.7	96.0	160.0
+	72	58	124	0	1.43	159.5	116.0	172.0
+	72	58	124	0	1.92	166.7	104.0	128.0
+	72	58	124	0	1.73	124.2	104.0	188.0
+	72	58	124	0	1.42	134.7	108.0	180.0
+	72	58	124	0	1.19	143.7	84.0	172.0
+	72	58	124	0	1.11	123.7	92.0	136.0
+	72	58	124	0	1.69	114.6	104.0	160.0
+	72	58	124	0	1.61	119.9	120.0	168.0
+	72	58	124	0	1.51	131.7	96.0	148.0
+	72	58	124	0	.78	178.5	100.0	148.0
+	72	58	124	0	1.48	116.4	116.0	160.0
+	72	58	124	0	1.62	106.4	84.0	152.0
+	72	58	124	0	1.95	134.7	100.0	148.0
+	72	58	124	0	1.72	131.2	88.0	156.0

+	72	58	124	0	1.35	98.8	88.0	108.0
*	99	105	105	1	.71	324.4	108.0	260.0
*	99	105	105	1	.74	347.2	128.0	300.0
*	99	105	105	1	.88	368.5	108.0	204.0
*	99	105	105	1	.95	426.3	120.0	1228.0
*	99	105	105	1	.93	341.4	96.0	256.0
*	99	105	105	1	.96	325.8	128.0	260.0
*	99	105	105	1	.98	353.1	108.0	216.0
*	99	105	105	1	.98	344.7	100.0	216.0
*	99	105	105	1	.97	383.1	112.0	1224.0
*	99	105	105	1	.88	329.6	92.0	468.0
*	99	105	105	1	1.08	416.4	172.0	1296.0
*	99	105	105	1	1.18	352.1	108.0	1260.0
*	99	105	105	1	1.19	343.0	148.0	332.0
*	99	105	105	1	1.17	382.2	116.0	356.0
*	99	105	105	1	1.21	407.5	124.0	1224.0
*	99	105	105	1	1.21	343.5	136.0	1224.0
*	99	105	105	1	1.16	335.2	148.0	428.0
*	99	105	105	1	1.14	385.1	108.0	204.0
*	99	105	105	1	1.03	368.8	100.0	540.0
*	99	105	105	1	.95	367.8	108.0	260.0
*	99	105	105	1	.66	351.5	108.0	380.0
*	99	105	105	1	.93	429.3	120.0	1224.0
*	99	105	105	1	1.01	387.3	168.0	492.0
*	99	105	105	1	1.03	346.8	108.0	472.0
*	99	105	105	1	.99	330.6	108.0	260.0
*	99	105	105	1	1.01	410.1	112.0	1224.0
*	99	105	105	1	.99	417.0	116.0	1224.0
*	99	105	105	1	1.03	418.6	140.0	1272.0
*	99	105	105	1	1.08	325.9	108.0	212.0
*	99	105	105	1	.97	392.6	116.0	172.0
*	99	105	105	1	1.12	403.0	96.0	500.0
*	99	105	105	1	1.12	364.8	148.0	276.0
*	99	105	105	1	1.06	392.8	108.0	1224.0
*	99	105	105	1	1.10	392.6	108.0	260.0
*	99	105	105	1	1.22	349.1	112.0	172.0
*	99	105	105	1	1.21	336.1	112.1	288.0
*	99	105	105	1	1.21	380.5	116.0	1224.0
*	99	105	105	1	1.12	355.2	108.0	260.0
*	99	105	105	1	.98	278.5	112.0	172.0
#	70	74	106	0	.75	314.2	152.0	364.0
#	70	74	106	0	1.19	288.9	144.0	632.0
#	70	74	106	0	1.23	308.3	112.0	292.0
#	70	74	106	0	.87	303.4	88.0	448.0
#	70	74	106	0	0.32	331.4	112.0	1264.0
#	70	74	106	0	1.53	144.4	100.0	176.0
#	70	74	106	0	1.73	143.8	80.0	152.0
#	70	74	106	0	1.58	140.7	96.0	156.0
#	70	74	106	0	1.19	151.3	96.0	164.0
#	70	74	106	0	1.04	350.9	108.0	628.0
#	70	74	106	0	1.43	324.6	144.0	600.0
#	70	74	106	0	1.58	287.6	112.0	568.0

#	70	74	106	0	1.61	449.5	100.0	700.0
#	70	74	106	0	1.34	305.6	140.0	544.0
#	70	74	106	0	.81	355.5	128.0	1340.0
#	70	74	106	0	.65	408.1	100.0	1332.0
#	70	74	106	0	1.32	301.9	136.0	260.0
#	70	74	106	0	1.81	400.9	152.0	676.0
#	70	74	106	0	1.86	318.8	112.0	628.0
#	70	74	106	0	1.65	346.4	104.0	1224.0
#	70	74	106	0	1.17	326.9	112.0	1224.0

Inspiration Direct Data Set: Each

Test Set

7 Abnormals (STATE=0)

M
C
D
G
S
B
E

5 Normals (STATE=1)

K
L
F
Y
N

```
DATA BREATH;
TITLE 'POWER SPECTRA DATA ON INSPIRATORY SOUND';
COMMENT STATE: NORMAL= 1  ABNORMAL= 0;
COMMENT DIRECT TEST DATA;
INPUT ID S FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;
CARDS;
  B    82   70   85   0   1.41     902.7    1492     1496
  B    82   70   85   0   1.41     704.2     256     1496
  B    82   70   85   0   1.08     842       404     1488
  B    82   70   85   0    .84     949.1     424     1464
  B    82   70   85   0   1.37     784.5    1472     1488
  B    82   70   85   0   1.42     963      1476     1480
  B    82   70   85   0   1.32     853.9    1436     1496
  B    82   70   85   0   1.08     970       172     1496
  B    82   70   85   0    .77    1017      1460     1492
  B    82   70   85   0   1.20     727.4     260     1464
  B    82   70   85   0   1.41     847.5     172     1496
  B    82   70   85   0   1.30     951.5     240     1488
  B    82   70   85   0   1.08    1129.0    1468     1496
  B    82   70   85   0   1.06     937.7     260     1496
  B    82   70   85   0   1.38     870.1     112     1496
  B    82   70   85   0   1.21     909.2    1320     1492
  B    82   70   85   0   1.00     869.2     172     1496
  C    77   78   99   0   1.34     402.7     452      664
  C    77   78   99   0   1.34     369.7     464      592
  C    77   78   99   0   1.30     329.3     104      588
  C    77   78   99   0   1.20     399.4     444      716.0
  C    77   78   99   0   1.12     430.7     696      736.0
  C    77   78   99   0   1.09     454.2     688      732.0
  C    77   78   99   0   0.99     455.4     600.0    608.0
  C    77   78   99   0   0.98     442.0     568.0    648.0
  C    77   78   99   0   1.40     444.8     588.0    788.0
  C    77   78   99   0   1.40     419.4     436.0    636.0
  C    77   78   99   0   1.29     395.2     472.0    620.0
  C    77   78   99   0   1.24     421.7     160.0    744.0
  C    77   78   99   0   1.13     427.9     680.0    684.0
  D   102  100   97   0   1.00     371.7     108.0    180.0
  D   102  100   97   0   1.27     499.1     100.0   1468.0
  D   102  100   97   0   1.15     423.3     104.0   1336.0
  D   102  100   97   0   1.02     672.0     172.0   1488.0
  D   102  100   97   0    .74     500.2     120.0   1432.0
  D   102  100   97   0   1.19     470.6     100.0   1432.0
  D   102  100   97   0   1.36     579.0     100.0   1452.0
  D   102  100   97   0   1.27     396.0     104.0    432.0
  D   102  100   97   0   1.04     340.7     104.0    260.0
  D   102  100   97   0    .99     614.9     740.0   1360.0
  D   102  100   97   0   1.44     560.7     712.0    904.0
  D   102  100   97   0   1.41     458.1     112.0    896.0
  D   102  100   97   0   1.19     413.3     104.0    212.0
  D   102  100   97   0    .75     643.1     124.0   1460.0
  D   102  100   97   0   1.25     394.9     604.0    796.0
  D   102  100   97   0   1.54     258.8     180.0    600.0
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D	102	100	97	0	1.39	223.6	104.0	608.0
D	102	100	97	0	1.19	255.3	108.0	704.0
D	102	100	97	0	.84	372.9	604.0	612.0
E	90	72	81	0	1.00	364.6	104.0	648.0
E	90	72	81	0	1.07	390.1	616.0	708.0
E	90	72	81	0	1.08	368.1	216.0	704.0
E	90	72	81	0	.84	356.1	116.0	700.0
E	90	72	81	0	.80	323.5	104.0	612.0
E	90	72	81	0	1.18	354.1	200.0	624.0
E	90	72	81	0	1.21	351.9	508.0	624.0
E	90	72	81	0	1.16	318.7	208.0	624.0
E	90	72	81	0	1.10	302.5	100.0	600.0
E	90	72	81	0	.97	414.2	612.0	724.0
E	90	72	81	0	1.15	430.0	608.0	748.0
E	90	72	81	0	1.14	412.7	192.0	744.0
E	90	72	81	0	1.13	383.7	104.0	724.0
E	90	72	81	0	1.05	405.1	108.0	700.0
E	90	72	81	0	1.01	378.0	208.0	716.0
E	90	72	81	0	1.25	372.0	100.0	692.0
E	90	72	81	0	1.33	404.3	224.0	708.0
E	90	72	81	0	1.29	419.1	228.0	740.0
E	90	72	81	0	1.09	365.7	200.0	628.0
F	146	141	97	1	.50	315.4	100.0	512.0
F	146	141	97	1	.82	242.8	120.0	192.0
F	146	141	97	1	1.12	288.2	104.0	568.0
F	146	141	97	1	1.51	274.0	104.0	588.0
F	146	141	97	1	1.60	277.2	108.0	520.0
F	146	141	97	1	1.74	400.0	100.0	1032.0
F	146	141	97	1	0.64	310.3	112.0	172.0
F	146	141	97	1	1.28	314.0	104.0	556.0
F	146	141	97	1	1.66	263.6	100.0	516.0
F	146	141	97	1	1.87	404.1	120.0	1048.0
F	146	141	97	1	1.88	620.1	1028.0	1036.0
F	146	141	97	1	1.88	624.7	1028.0	1036.0
F	146	141	97	1	1.80	216.2	104.0	176.0
F	146	141	97	1	.45	380.4	100.0	692.0
F	146	141	97	1	.72	302.5	100.0	628.0
F	146	141	97	1	.83	259.9	100.0	612.0
F	146	141	97	1	1.07	291.9	100.0	600.0
F	146	141	97	1	1.42	361.5	168.0	1228.0
F	146	141	97	1	1.66	303.7	104.0	592.0
F	146	141	97	1	1.65	314.4	136.0	604.0
F	146	141	97	1	1.58	172.6	100.0	172.0
F	146	141	97	1	1.48	224.4	120.0	492.0
F	146	141	97	1	.66	308.5	100.0	256.0
F	146	141	97	1	.98	264.7	100.0	456.0
F	146	141	97	1	1.1	300.8	104.0	584.0
F	146	141	97	1	1.27	302.0	100.0	580.0
F	146	141	97	1	1.40	258.8	120.0	604.0
F	146	141	97	1	1.70	287.1	104.0	600.0
G	78	91	118	0	.15	434.5	612.0	736.0
G	78	91	118	0	.46	343.8	104.0	728.0

G	78	91	118	0	1.1	482.2	160.0	1020.0
G	78	91	118	0	1.2	427.7	228.0	716.0
G	78	91	118	0	1.27	404.6	192.0	716.0
G	78	91	118	0	1.46	343.7	208.0	712.0
G	78	91	118	0	1.50	484.0	236.0	1024.0
G	78	91	118	0	1.50	419.0	188.0	1016.0
G	78	91	118	0	1.48	368.8	172.0	760.0
G	78	91	118	0	1.25	425.4	708.0	764.0
G	78	91	118	0	1.45	457.0	180.0	780.0
G	78	91	118	0	1.36	497.3	688.0	740.0
G	78	91	118	0	1.21	406.2	100.0	748.0
G	78	91	118	0	0.72	513.2	180.0	844.0
G	78	91	118	0	1.16	436.4	176.0	756.0
G	78	91	118	0	1.04	381.1	208.0	772.0
G	78	91	118	0	1.17	427.7	244.0	744.0
S	92	95	103	0	1.60	278.5	228.0	676.0
S	92	95	103	0	1.52	208.4	172.0	304.0
S	92	95	103	0	1.38	183.6	112.0	260.0
S	92	95	103	0	1.19	220.7	120.0	284.0
S	92	95	103	0	1.97	785.3	928.0	932.0
S	92	95	103	0	2.22	311.2	104.0	144.0
S	92	95	103	0	2.08	505.4	172.0	1376.0
S	92	95	103	0	1.87	318.9	92.0	636.0
S	92	95	103	0	1.29	187.7	76.0	156.0
S	92	95	103	0	1.82	689.9	120.0	1436.0
S	92	95	103	0	2.18	589.0	120.0	1412.0
S	92	95	103	0	2.04	562.5	120.0	1332.0
S	92	95	103	0	1.63	572.4	120.0	1224.0
S	92	95	103	0	.62	575.7	120.0	260.0
S	92	95	103	0	1.15	334.4	120.0	608.0
S	92	95	103	0	1.80	361.6	204.0	668.0
S	92	95	103	0	1.80	379.0	160.0	776.0
S	92	95	103	0	1.60	417.4	120.0	420.0
S	92	95	103	0	1.38	386.5	120.0	260.0
Y	101	113	113	1	.69	447.4	116.0	1224.0
Y	101	113	113	1	1.05	322.0	112.0	172.0
Y	101	113	113	1	1.18	367.9	108.0	268.0
Y	101	113	113	1	1.21	481.2	112.0	260.0
Y	101	113	113	1	1.23	395.1	116.0	336.0
Y	101	113	113	1	.97	324.6	112.0	184.0
Y	101	113	113	1	1.06	175.1	112.0	248.0
Y	101	113	113	1	1.30	131.0	88.0	168.0
Y	101	113	113	1	1.45	183.0	124.0	276.0
Y	101	113	113	1	1.57	170.5	84.0	260.0
Y	101	113	113	1	1.39	150.6	96.0	188.0
Y	101	113	113	1	.87	144.9	92.0	136.0
Y	101	113	113	1	1.17	146.6	104.0	192.0
Y	101	113	113	1	1.49	188.2	112.0	260.0
Y	101	113	113	1	1.53	141.5	92.0	124.0
Y	101	113	113	1	1.48	161.2	84.0	428.0
Y	101	113	113	1	1.29	136.2	100.0	156.0
Y	101	113	113	1	1.09	179.3	96.0	180.0

Y	101	113	113	1	1.32	125.0	84.0	132.0
Y	101	113	113	1	1.47	185.9	112.0	152.0
Y	101	113	113	1	1.31	114.1	80.0	156.0
Y	101	113	113	1	1.29	139.2	116.0	152.0
Y	101	113	113	1	1.17	124.0	96.0	152.0
K	102	105	104	1	.95	393.3	496.0	600.0
K	102	105	104	1	1.27	364.0	484.0	608.0
K	102	105	104	1	1.21	356.3	452.0	604.0
K	102	105	104	1	1.16	399.4	472.0	608.0
K	102	105	104	1	1.01	310.3	152.0	592.0
K	102	105	104	1	.73	269.2	128.0	592.0
K	102	105	104	1	.69	352.4	508.0	596.0
K	102	105	104	1	1.12	381.5	188.0	612.0
K	102	105	104	1	1.17	398.6	500.0	612.0
K	102	105	104	1	1.10	220.2	108.0	580.0
K	102	105	104	1	0.84	339.5	192.0	612.0
K	102	105	104	1	.89	295.5	108.0	600.0
K	102	105	104	1	1.35	431.3	464.0	580.0
K	102	105	104	1	1.30	432.1	448.0	596.0
K	102	105	104	1	1.25	373.7	532.0	604.0
K	102	105	104	1	1.06	364.6	484.0	600.0
K	102	105	104	1	.90	220.2	88.0	584.0
K	102	105	104	1	.85	400.9	484.0	596.0
K	102	105	104	1	1.37	445.6	476.0	600.0
K	102	105	104	1	1.34	405.3	460.0	600.0
K	102	105	104	1	1.22	403.4	488.0	588.0
K	102	105	104	1	0.95	319.0	468.0	592.0
L	110	102	92	1	.70	395.5	472.0	536.0
L	110	102	92	1	0.87	397.9	480.0	644.0
L	110	102	92	1	0.87	379.7	488.0	552.0
L	110	102	92	1	0.87	424.1	488.0	608.0
L	110	102	92	1	0.74	395.4	460.0	604.0
L	110	102	92	1	1.38	302.5	464.0	628.0
L	110	102	92	1	1.18	373.9	472.0	572.0
L	110	102	92	1	1.10	395.7	520.0	540.0
L	110	102	92	1	0.99	402.4	512.0	600.0
L	110	102	92	1	.92	395.6	492.0	580.0
L	110	102	92	1	.93	304.0	500.0	580.0
L	110	102	92	1	.98	428.7	500.0	568.0
L	110	102	92	1	1.12	421.5	504.0	636.0
L	110	102	92	1	.93	429.6	496.0	620.0
L	110	102	92	1	.77	435.8	476.0	544.0
L	110	102	92	1	1.03	332.1	504.0	596.0
L	110	102	92	1	1.12	371.5	508.0	540.0
L	110	102	92	1	1.05	361.9	488.0	580.0
L	110	102	92	1	1.04	394.3	472.0	596.0
L	110	102	92	1	1.11	353.8	464.0	616.0
M	53	38	68	0	1.17	243.8	84.0	596.0
M	53	38	68	0	1.91	279.4	532.0	580.0
M	53	38	68	0	2.0	205.2	84.0	560.0
M	53	38	68	0	2.3	241.1	108.0	576.0
M	53	38	68	0	1.91	240.0	72.0	592.0

M	53	38	68	0	1.57	292.5	100.0	596.0
M	53	38	68	0	0.89	198.3	84.0	448.0
M	53	38	68	0	1.16	184.3	104.0	140.0
M	53	38	68	0	1.25	299.3	536.0	600.0
M	53	38	68	0	1.17	251.9	84.0	604.0
M	53	38	68	0	1.08	209.8	96.0	544.0
M	53	38	68	0	1.28	154.8	76.0	148.0
M	53	38	68	0	0.83	235.3	144.0	596.0
M	53	38	68	0	1.42	366.8	588.0	608.0
M	53	38	68	0	1.46	396.3	452.0	592.0
M	53	38	68	0	1.49	354.6	588.0	596.0
M	53	38	68	0	1.56	377.1	540.0	604.0
M	53	38	68	0	1.48	356.9	588.0	604.0
M	53	38	68	0	0.86	322.6	120.0	624.0
M	53	38	68	0	1.19	322.5	80.0	604.0
M	53	38	68	0	1.21	287.1	104.0	588.0
M	53	38	68	0	1.12	290.5	96.0	600.0
M	53	38	68	0	1.03	165.1	120.0	596.0
M	53	38	68	0	1.14	241.1	84.0	588.0
N	91	97	107	1	.45	315.7	188.0	588.0
N	91	97	107	1	.81	353.5	596.0	620.0
N	91	97	107	1	.95	401.1	576.0	616.0
N	91	97	107	1	.93	388.2	592.0	620.0
N	91	97	107	1	.83	384.8	592.0	612.0
N	91	97	107	1	.67	411.0	600.0	608.0
N	91	97	107	1	.53	256.4	100.0	624.0
N	91	97	107	1	.55	435.6	444.0	688.0
N	91	97	107	1	.70	383.5	600.0	644.0
N	91	97	107	1	.78	366.5	452.0	636.0
N	91	97	107	1	.77	424.2	604.0	628.0
N	91	97	107	1	.71	367.6	452.0	664.0
N	91	97	107	1	.61	391.3	616.0	636.0
N	91	97	107	1	.84	403.3	452.0	628.0
N	91	97	107	1	1.07	404.1	444.0	616.0
N	91	97	107	1	1.15	396.1	448.0	648.0
N	91	97	107	1	1.09	416.8	452.0	624.0
N	91	97	107	1	1.07	401.3	424.0	620.0
N	91	97	107	1	1.01	341.8	428.0	652.0
N	91	97	107	1	.60	345.2	116.0	648.0
N	91	97	107	1	.86	406.1	260.0	664.0
N	91	97	107	1	.89	405.9	464.0	628.0
N	91	97	107	1	.92	404.4	424.0	660.0
N	91	97	107	1	.84	404.6	204.0	684.0
N	91	97	107	1	.74	413.4	484.0	636.0

APPENDIX C

EXPIRATION DIRECT DATA SET: MEAN.

Calibration or Training Set

7 Abnormals (STATE=0)
P
Q
T
U
X
+
#

5 Normals (STATE=1)
H
I
V
W
*

EXPIRATION DIRECT DATA SET: MEAN.

Calibration or Training Set

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
					ID *			
MPF	33	132 29090909	32 27902147	90 40000000	241 70000000	5 61905639	4365 6000000	1041 9352273
FPK	33	93 57575758	13 67257817	64 00000000	120 00000000	2 38009036	3088 0000000	186 9393939
FMAX	33	149 57575758	22 44859448	112 00000000	192 00000000	3 90779871	4936 0000000	503 9393939
STATE	33	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 0000000	0 0000000
					ID *			
MPF	30	484 89666667	71 43159971	342 40000000	603 6000000	13 04156616	14546 900000	5102 47344
FPK	30	128 80000000	41 46822631	108 00000000	260 0000000	7 57102766	3864 000000	1719 61379
FMAX	30	717 33333333	523 11779733	124 00000000	1476 0000000	95 50780594	21520 000000	273652 22989
STATE	30	1 00000000	0 00000000	1 00000000	1 0000000	0 00000000	30 000000	0 00000
					ID #			
MPF	36	347 47777778	98 56043284	127 60000000	497 3000000	16 42673881	12509 200000	9714 15892
FPK	36	150 22222222	122 48641000	72 00000000	576 0000000	20 41440167	5408 000000	15002 92063
FMAX	36	652 11111111	326 07587003	152 00000000	1372 0000000	54 34597834	23476 000000	106325 47302
STATE	36	0 00000000	0 00000000	0 00000000	0 0000000	0 00000000	0 000000	0 00000
					ID H			
MPF	24	406 25416667	60 48871960	246 80000000	482 0000000	12 34720819	9750 100000	3658 88520
FPK	24	148 50000000	45 88549074	92 00000000	260 0000000	9 36633658	3564 000000	2105 47826
FMAX	24	432 00000000	370 00963560	256 00000000	1400 0000000	75 52790059	10368 000000	136907 13043
STATE	24	1 00000000	0 00000000	1 00000000	1 0000000	0 00000000	24 000000	0 00000
					ID I			
MPF	24	420 32916667	51 46431840	298 30000000	514 60000000	10 50511000	10087 900000	2648 576069
FPK	24	412 50000000	249 80079020	84 00000000	668 00000000	50 99037278	9900 000000	62400 434783
FMAX	24	724 00000000	47 66550115	624 00000000	788 00000000	9 72967968	17376 000000	2272 000000
STATE	24	1 00000000	0 00000000	1 00000000	1 00000000	0 00000000	24 000000	0 000000
					ID P			
MPF	40	391 47500000	119 60227197	154 10000000	625 3000000	18 91077964	15659 000000	14304 70346
FPK	40	138 40000000	47 58625098	60 00000000	292 0000000	7 52404692	5536 000000	2264 45128
FMAX	40	856 30000000	487 98351170	172 00000000	1452 0000000	77 15696788	34252 000000	238127 90769
STATE	40	0 00000000	0 00000000	0 00000000	0 0000000	0 00000000	0 000000	0 00000

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
				ID=Q				
MPF	36	213 10555556	86 25402001	95 20000000	417 00000000	14 37567000	7671 800000	7439 755968
FPK	36	161 33333333	179 20969362	60 00000000	600 00000000	29 86828227	5808 000000	32116 114286
FMAX	36	551 44444444	152 56182718	104 00000000	628 00000000	25 42697120	19852 000000	23275 111111
STATE	36	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 000000	0 000000
				ID=T				
MPF	36	281 48611111	102 53018274	94 60000000	414 60000000	17 08836379	10133 500000	10512 438373
FPK	36	316 88888889	246 91395584	76 00000000	592 00000000	41 15232597	11408 000000	60966 501587
FMAX	36	541 11111111	152 20020232	112 00000000	616 00000000	25 36670039	19480 000000	23164 901587
STATE	36	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 000000	0 000000
				ID=U				
MPF	23	145 09130435	44 57346248	96 90000000	262 00000000	9 29420941	3337 100000	1986 793557
FPK	23	95 30434783	20 31218797	68 00000000	172 00000000	4 23538397	2192 000000	412 584980
FMAX	23	217 56521739	117 78401886	100 00000000	560 00000000	24 55966568	5004 000000	13873 075099
STATE	23	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 000000	0 000000
				ID=V				
MPF	24	280 37083333	92 52394510	132 20000000	434 60000000	18 88637121	6728 900000	8560 680417
FPK	24	300 33333333	254 45434658	88 00000000	628 00000000	51 94027600	7208 000000	64747 014493
FMAX	24	497 66666667	214 76917167	144 00000000	740 00000000	43 83957359	11944 000000	46125 797101
STATE	24	1 00000000	0 00000000	1 00000000	1 00000000	0 00000000	24 000000	0 000000
				ID=W				
MPF	22	303 75454545	78 07004625	148 90000000	475 7000000	16 64458979	6682 600000	6094 93212
FPK	22	137 81818182	48 78293648	84 00000000	260 0000000	10 40055700	3032 000000	2379 77489
FMAX	22	485 63636364	332 14720567	192 00000000	1404 0000000	70 81402218	10684 000000	110321 76623
STATE	22	1 00000000	0 00000000	1 00000000	1 0000000	0 00000000	22 000000	0 00000
				ID=X				
MPF	20	247 37500000	54 14529065	141 00000000	356 50000000	12 10725506	4947 5000000	2931 712500
FPK	20	118 20000000	32 45661071	80 00000000	196 00000000	7 25751879	2364 0000000	1053 431579
FMAX	20	474 80000000	209 32412540	120 00000000	772 00000000	46 80629737	9496 0000000	43816 589474
STATE	20	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 0000000	0 000000

Expiration Direct Data Set: Mean

Test Set

7 Abnormals (STATE=0)

M
C
D
G
S
B
E

5 Normals (STATE=1)

K
L
F
Y
N

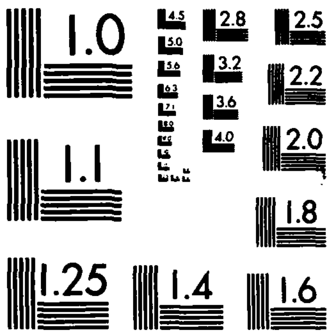
Expiration Direct Data Set: Mean

Test Set

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID-B								
MPF	25	629 44400000	133 61529067	278 90000000	799 8000000	26 72305813	15736 100000	17853 04590
FPK	25	286 40000000	229 82602116	108 00000000	956 0000000	45 96520423	7160 000000	52820 00000
FMAX	25	1216 48000000	321 87848639	604 00000000	1488 0000000	64 37569728	30412 000000	103605 76000
STATE	25	0 00000000	0 00000000	0 00000000	0 0000000	0 00000000	0 000000	0 00000
ID-C								
MPF	22	408 67727273	69 62449577	217 60000000	476 90000000	14 84399237	8990 900000	4847 570411
FPK	22	472 00000000	171 12290209	76 00000000	608 00000000	36 48352531	10384 000000	29283 047619
FMAX	22	620 72727273	18 00048099	584 00000000	684 00000000	3 83771544	13656 000000	324 017316
STATE	22	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 000000	0 000000
ID-D								
MPF	16	353 86250000	82 81757362	236 20000000	495 6000000	20 70439340	5661 800000	6858 75050
FPK	16	217 75000000	53 42596123	100 00000000	292 0000000	13 35649031	3484 000000	2854 33333
FMAX	16	855 75000000	354 62496622	392 00000000	1360 0000000	88 65624156	13692 000000	125758 86667
STATE	16	0 00000000	0 00000000	0 00000000	0 0000000	0 00000000	0 000000	0 00000
ID-E								
MPF	26	271 19615385	97 50866825	129 50000000	558 70000000	19 12302316	7051 100000	9507 940385
FPK	26	195 84615385	174 22185679	68 00000000	676 00000000	34 16771721	5092 000000	30353 255385
FMAX	26	510 30769231	200 68418358	128 00000000	724 00000000	39 35740647	13268 000000	40274 141538
STATE	26	0 00000000	0 00000000	0 00000000	0 00000000	0 00000000	0 000000	0 000000
ID-F								
[illegible]	[illegible]	185 28666667	29 73376965	129 40000000	246 10000000	5 42861879	5558 600000	884 097057
[illegible]	[illegible]	121 33333333	30 14142908	80 00000000	176 00000000	5 50304687	3640 000000	908 505747
[illegible]	[illegible]	360 93333333	178 93688607	148 00000000	632 00000000	32 66925629	10828 000000	32018 409195
[illegible]	[illegible]	1 00000000	0 00000000	1 00000000	1 00000000	0 00000000	30 000000	0 000000
ID-G								
[illegible]	[illegible]	[illegible]	77 16794239	117 70000000	405 20000000	16 83942558	6113 800000	5954 891333
[illegible]	[illegible]	[illegible]	44 71965585	80 00000000	224 00000000	9 75862895	3436 000000	1999 847619
[illegible]	[illegible]	[illegible]	232 48782866	124 00000000	788 00000000	50 73300318	12500 000000	54050 590476
[illegible]	[illegible]	[illegible]	0 00000000	0 00000000	0 00000000	0 00000000	0 000000	0 000000

AD-A184 344 DISCRIMINANT ANALYSIS OF RESPIRATORY SOUNDS OF PULMONARY INSUFFICIENT PAT (U) TEXAS A AND M UNIV COLLEGE STATION BIOENGINEERING PROGRAM 2/2

UNCLASSIFIED C S LESSARD ET AL APR 87 USAFSAM-TR-86-33 F/G 6/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=K								
MPF	20	361.54000000	32.56522847	288.90000000	412.00000000	7.28180646	7230.800000	1060.494105
FPK	20	401.00000000	196.13904842	148.00000000	596.00000000	43.85802453	8020.000000	38470.526316
FMAX	20	605.20000000	6.63007502	592.00000000	616.00000000	1.48252984	12104.000000	43.957895
STATE	20	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	20.000000	0.000000
ID=L								
MPF	20	406.78000000	23.51500305	350.10000000	440.60000000	5.25811453	8135.600000	552.9553684
FPK	20	473.20000000	78.50283267	152.00000000	532.00000000	17.55376703	9464.000000	6162.6947368
FMAX	20	598.80000000	17.41626584	560.00000000	624.00000000	3.89439543	11976.000000	303.3263158
STATE	20	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	20.000000	0.0000000
ID=M								
MPF	28	226.03928571	54.01982036	117.90000000	351.60000000	10.20878647	6329.100000	2918.140992
FPK	28	122.14285714	114.32238830	68.00000000	576.00000000	21.60490062	3420.000000	13069.608466
FMAX	28	525.71428571	167.30518956	116.00000000	616.00000000	31.61770890	14720.000000	27991.026455
STATE	28	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000
ID=N								
MPF	28	350.66071429	42.73994003	258.50000000	498.20000000	8.07708945	9818.500000	1826.702474
FPK	28	336.14285714	176.43878684	112.00000000	608.00000000	33.34379654	9412.000000	31130.645503
FMAX	28	616.57142857	30.74799430	564.00000000	736.00000000	5.81082473	17264.000000	945.439153
STATE	28	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	28.000000	0.000000
ID=S								
MPF	27	366.53703704	142.68821888	129.60000000	695.6000000	27.46036053	9896.500000	20359.92781
FPK	27	142.96296296	130.02528792	56.00000000	600.0000000	25.02337833	3860.000000	16906.57550
FMAX	27	651.55555556	423.29452679	168.00000000	1428.0000000	81.46306966	17592.000000	179178.25641
STATE	27	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.00000
ID=Y								
MPF	33	253.61515152	127.52452980	107.60000000	523.5000000	22.19917122	8369.300000	16262.505701
FPK	33	109.09090909	34.63051728	76.00000000	252.0000000	6.02839927	3600.000000	1199.272727
FMAX	33	371.87878788	310.57122347	140.00000000	1364.0000000	54.06351059	12272.000000	96454.484848
STATE	33	1.00000000	0.00000000	1.00000000	1.0000000	0.00000000	33.000000	0.000000

APPENDIX D

INSPIRATION DIRECT DATA SET: MEAN.

Calibration or Training Set

7 Abnormals (STATE=0)

P
Q
T
U
X
+
#

5 Normals (STATE=1)

H
I
V
W
*

INSPIRATION DIRECT DATA SET: MEAN.

Calibration or Training Set

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=+								
MPF	20	139.52000000	25.94333096	98.80000000	196.30000000	5.80110516	2790.4000000	673.05642105
FPK	20	98.00000000	13.26649916	68.00000000	120.00000000	2.96647939	1960.0000000	176.00000000
FMAX	20	156.00000000	21.71586856	108.00000000	204.00000000	4.85581583	3120.0000000	471.57894737
STATE	20	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000
ID=*								
MPF	39	366.87179487	34.45553159	278.50000000	429.3000000	5.51730066	14308.000000	1187.18366
FPK	39	117.74615385	18.46212120	92.00000000	172.0000000	2.95630538	4592.100000	340.84992
FMAX	39	591.38461538	446.01773716	172.00000000	1296.0000000	71.41999682	23064.000000	198931.82186
STATE	39	1.00000000	0.00000000	1.00000000	1.0000000	0.00000000	39.000000	0.00000
ID=#								
MPF	21	300.14761905	87.00586543	140.70000000	449.5000000	18.98623639	6303.100000	7570.02062
FPK	21	115.61904762	21.46270298	80.00000000	152.0000000	4.68354576	2428.000000	460.64762
FMAX	21	636.76190476	409.52385825	152.00000000	1340.0000000	89.36543235	13372.000000	167709.79048
STATE	21	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.00000
ID=H								
MPF	18	619.09444444	51.94969821	513.10000000	689.2000000	12.24466129	11143.700000	2698.771144
FPK	18	225.77777778	40.58912569	172.00000000	260.0000000	9.56694867	4064.000000	1647.477124
FMAX	18	1322.22222222	273.43298040	260.00000000	1472.0000000	64.44877155	23800.000000	74765.594771
STATE	18	1.00000000	0.00000000	1.00000000	1.0000000	0.00000000	18.000000	0.000000
ID=I								
MPF	29	542.03793103	111.10369807	368.30000000	828.8000000	20.63143879	15719.100000	12344.03172
FPK	29	500.68965517	239.33734462	152.00000000	1364.0000000	44.44382915	14520.000000	57282.36453
FMAX	29	998.89655172	319.32589095	632.00000000	1484.0000000	59.29732931	28968.000000	101969.02463
STATE	29	1.00000000	0.00000000	1.00000000	1.0000000	0.00000000	29.000000	0.00000
ID=P								
MPF	25	455.16800000	158.40528116	255.50000000	822.6000000	31.68105623	11379.200000	25092.23310
FPK	25	199.36000000	234.67901483	84.00000000	1316.0000000	46.93580297	4984.000000	55074.24000
FMAX	25	964.96000000	511.66822584	240.00000000	1484.0000000	102.33364517	24124.000000	261804.37333
STATE	25	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.00000

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=Q								
MPF	37	205.61081081	89.43860335	94.50000000	453.00000000	14.70361582	7607.600000	7999.263769
FPK	37	141.18918919	164.04027924	56.00000000	608.00000000	26.96805578	5224.000000	26909.213213
FMAX	37	536.21621622	182.55457862	108.00000000	680.00000000	30.01178785	19840.000000	33326.174174
STATE	37	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000
ID=T								
MPF	31	259.19032258	106.68721371	98.70000000	419.7000000	19.16158924	8034.900000	11382.161570
FPK	31	197.41935484	180.14378964	76.00000000	592.0000000	32.35477975	6120.000000	32451.784946
FMAX	31	603.87096774	293.31663687	124.00000000	1224.0000000	52.68122315	18720.000000	86034.649462
STATE	31	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.000000
ID=U								
MPF	22	154.65454545	62.88946257	93.80000000	350.3000000	13.40807847	3402.4000000	3955.084502
FPK	22	89.45454545	13.72077768	52.00000000	108.0000000	2.92527963	1968.0000000	188.259740
FMAX	22	277.63636364	277.33880697	104.00000000	1352.0000000	59.12883232	6108.0000000	76916.813853
STATE	22	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.0000000	0.000000
ID=V								
MPF	27	303.12962963	103.89385417	157.10000000	494.90000000	19.99438156	8184.500000	10793.932934
FPK	27	262.37037037	240.07244870	76.00000000	644.00000000	46.20196429	7084.000000	57634.780627
FMAX	27	532.88888889	199.77012430	156.00000000	692.00000000	38.44577835	14388.000000	39908.102564
STATE	27	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	27.000000	0.000000
ID=W								
MPF	21	280.01904762	88.57784497	134.90000000	453.40000000	19.32927045	5880.4000000	7846.034619
FPK	21	125.71428571	36.80372652	76.00000000	260.00000000	8.03123155	2640.0000000	1354.514286
FMAX	21	423.80952381	145.70916891	172.00000000	660.00000000	31.79634743	8900.0000000	21231.161905
STATE	21	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	21.0000000	0.000000
ID=X								
MPF	25	188.77600000	63.49351200	105.50000000	365.80000000	12.69870240	4719.4000000	4031.426067
FPK	25	105.92000000	19.93723485	61.00000000	164.00000000	3.98744697	2648.0000000	397.493333
FMAX	25	250.72000000	125.70717296	136.00000000	568.00000000	25.14143459	6268.0000000	15802.293333
STATE	25	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.0000000	0.000000

Inspiration Direct Data Set: Mean

Test Set

7 Abnormals (STATE=0)
M
C
D
G
S
B
E

5 Normals (STATE=1)
K
L
F
Y
N

Inspiration Direct Data Set: Mean

Test Set

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=B								
MPF	17	895.76470588	103.93119684	704.2000000	1129.0000000	25.20701779	15228.000000	10801.69368
FPK	17	740.94117647	614.01714864	112.0000000	1492.0000000	148.92103293	12596.000000	377017.05882
FMAX	17	1489.41176471	10.57744548	1464.0000000	1496.0000000	2.56540735	25320.000000	111.88235
STATE	17	0.00000000	0.00000000	0.0000000	0.0000000	0.00000000	0.000000	0.00000
ID=C								
MPF	13	414.80000000	35.87680309	329.30000000	455.40000000	9.95043486	5392.4000000	1287.145000
FPK	13	488.61538462	185.03942754	104.00000000	696.00000000	51.32070338	6352.0000000	34239.589744
FMAX	13	673.53846154	64.92125408	588.00000000	788.00000000	18.00591619	8756.0000000	4214.769231
STATE	13	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.0000000	0.000000
ID=D								
MPF	19	444.64210526	130.23281851	223.60000000	672.0000000	29.87745763	8448.200000	16960.58702
FPK	19	231.78947368	232.74773634	100.00000000	740.0000000	53.39599274	4404.000000	54171.50877
FMAX	19	928.00000000	481.16525228	180.00000000	1488.0000000	110.38687946	17632.000000	231520.00000
STATE	19	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.00000
ID=E								
MPF	19	374.44210526	35.47777576	302.50000000	430.00000000	8.13915996	7114.400000	1258.672573
FPK	19	250.31578947	185.74207105	100.00000000	616.00000000	42.61215354	4756.000000	34500.116959
FMAX	19	682.52631579	49.78550483	600.00000000	748.00000000	11.42157813	12968.000000	2478.596491
STATE	19	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000
ID=F								
MPF	28	317.27857143	100.21188426	172.60000000	624.7000000	18.93826601	8883.800000	10042.421746
FPK	28	174.57142857	241.48482485	100.00000000	1028.0000000	45.63634228	4888.000000	58314.920635
FMAX	28	594.71428571	276.14500447	172.00000000	1228.0000000	52.18650054	16652.000000	76256.063492
STATE	28	1.00000000	0.00000000	1.00000000	1.0000000	0.00000000	28.000000	0.000000
ID=G								
MPF	17	426.62352941	50.04241363	343.70000000	513.2000000	12.13706807	7252.600000	2504.243162
FPK	17	269.64705882	195.38709693	100.00000000	708.0000000	47.38833168	4584.000000	38176.117647
FMAX	17	798.58823529	110.03582304	712.00000000	1024.0000000	26.68760712	13576.000000	12107.882353
STATE	17	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.000000

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=K								
MPF	22	358.01363636	63.28513927	220.20000000	445.60000000	13.49243703	7876.300000	4005.008853
FPK	22	371.81818182	166.13237303	88.00000000	532.00000000	35.41954094	8180.000000	27599.965368
FMAX	22	598.00000000	9.62140471	580.00000000	612.00000000	2.05129038	13156.000000	92.571429
STATE	22	1.00000000	0 00000000	1.00000000	1.00000000	0.00000000	22.000000	0.000000
ID=L								
MPF	20	384.79500000	38.62565925	302.50000000	435.80000000	8.63695998	7695.900000	1491.9415526
FPK	20	488.00000000	17.45972810	460.00000000	520.00000000	3.90411389	9760.000000	304.8421053
FMAX	20	587.00000000	33.36244343	536.00000000	644.00000000	7.46006914	11740.000000	1113.0526316
STATE	20	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	20.000000	0.0000000
ID=M								
MPF	24	271.51250000	68.68549820	154.80000000	396.30000000	14.02036861	6516.300000	4717.697663
FPK	24	227.66666667	210.93882622	72.00000000	588.00000000	43.05770760	5464.000000	44495.188406
FMAX	24	549.33333333	129.26368960	140.00000000	624.00000000	26.38584015	13184.000000	16709.101449
STATE	24	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000
ID=N								
MPF	25	384.89600000	38.76268051	256.40000000	435.60000000	7.75253610	9622.400000	1502.545400
FPK	25	440.48000000	154.66660920	100.00000000	616.00000000	30.93332184	11012.000000	23921.760000
FMAX	25	635.68000000	23.69022302	588.00000000	688.00000000	4.73804460	15892.000000	561.226667
STATE	25	1.00000000	0.00000000	1.00000000	1.00000000	0.00000000	25.000000	0.000000
ID=S								
MPF	19	414.11052632	176.26240821	183.60000000	785.3000000	40.43736973	7868.100000	31068.43655
FPK	19	175.15789474	186.16398481	76.00000000	928.0000000	42.70894720	3328.000000	34657.02924
FMAX	19	692.84210526	462.27376006	144.00000000	1436.0000000	106.05287391	13164.000000	213697.02924
STATE	19	0.00000000	0.00000000	0.00000000	0.0000000	0.00000000	0.000000	0.00000
ID=Y								
MPF	23	214.54347826	112.65157396	114.10000000	481.2000000	23.48947694	4934.5000000	12690.377115
FPK	23	102.08695652	12.92605910	80.00000000	124.0000000	2.69526964	2348.0000000	167.083004
FMAX	23	252.34782609	224.36630129	124.00000000	1224 0000000	46.78360785	5804.0000000	50340.237154
STATE	23	1.00000000	0.00000000	1.00000000	1 0000000	0.00000000	23.0000000	0.000000

APPENDIX E

PFT DIRECT DATA SET.

Calibration or Training Set

7 Abnormals (STATE=0)

P
Q
T
U
X
+
#

5 Normals (STATE=1)

H
I
V
W
*

PFT DIRECT DATA SET.

Calibration or Training Set

ID	FVC	FEV1	FEV1P	STATE
+	72	58	124	0
*	99	105	105	1
#	70	74	106	0
H	114	110	96	1
I	112	118	105	1
P	73	32	44	0
Q	102	83	81	0
T	83	76	91	0
U	73	66	90	0
V	101	106	104	1
W	107	114	106	1
X	93	78	85	0

PFT Direct Data Set.

Test Set

7 Abnormals (STATE=0)

M
C
D
G
S
B
E

5 Normals (STATE=1)

K
L
F
Y
N

PFT Direct Data Set.

Test Set

ID	FVC	FEV1	FEV1P	STATE
B	82	70	85	0
C	77	78	99	0
D	102	100	97	0
E	90	72	81	0
F	146	141	97	1
G	78	91	118	0
K	102	105	104	1
L	110	102	92	1
M	53	38	68	0
N	91	97	107	1
S	92	95	103	0
Y	101	113	113	1

APPENDIX F

EXPIRATION REGRESSION ANALYSIS DATA

14 Abnormals (STATE=0)

P
Q
T
U
X
+

M
C
D
G
S
B
E

10 Normals (STATE=1)

H
I
V
W
*
K
L
F
Y
N

EXPIRATION REGRESSION ANALYSIS DATA.

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=+								
FVC	33	72.00000000	0.00000000	72.00000000	72.00000000	0.00000000	2376.0000000	0.0000000
FEV1	33	58.00000000	0.00000000	58.00000000	58.00000000	0.00000000	1914.0000000	0.0000000
FEV1P	33	124.00000000	0.00000000	124.00000000	124.00000000	0.00000000	4092.0000000	0.0000000
MPF	33	132.29090909	32.27902147	90.40000000	241.70000000	5.61905639	4365.6000000	1041.9352273
FPK	33	93.57575758	13.67257817	64.00000000	120.00000000	2.38009036	3088.0000000	186.9393939
FMAX	33	149.57575758	22.44859448	112.00000000	192.00000000	3.90779871	4936.0000000	503.9393939
ID=*								
FVC	30	99.00000000	0.00000000	99.00000000	99.0000000	0.00000000	2970.000000	0.00000
FEV1	30	105.00000000	0.00000000	105.00000000	105.0000000	0.00000000	3150.000000	0.00000
FEV1P	30	105.00000000	0.00000000	105.00000000	105.0000000	0.00000000	3150.000000	0.00000
MPF	30	484.89666667	71.43159971	342.40000000	603.6000000	13.04156616	14546.900000	5102.47344
FPK	30	128.80000000	41.46822631	108.00000000	260.0000000	7.57102766	3864.000000	1719.61379
FMAX	30	717.33333333	523.11779733	124.00000000	1476.0000000	95.50780594	21520.000000	273652.22989
ID=#								
FVC	36	70.00000000	0.00000000	70.00000000	70.0000000	0.00000000	2520.000000	0.00000
FEV1	36	74.00000000	0.00000000	74.00000000	74.0000000	0.00000000	2664.000000	0.00000
FEV1P	36	106.00000000	0.00000000	106.00000000	106.0000000	0.00000000	3816.000000	0.00000
MPF	36	347.47777778	98.56043284	127.60000000	497.3000000	16.42673881	12509.200000	9714.15892
FPK	36	150.22222222	122.48641000	72.00000000	576.0000000	20.41440167	5408.000000	15002.92063
FMAX	36	652.11111111	326.07587003	152.00000000	1372.0000000	54.34597834	23476.000000	106325.47302
ID=B								
FVC	25	82.00000000	0.00000000	82.00000000	82.0000000	0.00000000	2050.000000	0.00000
FEV1	25	70.00000000	0.00000000	70.00000000	70.0000000	0.00000000	1750.000000	0.00000
FEV1P	25	85.00000000	0.00000000	85.00000000	85.0000000	0.00000000	2125.000000	0.00000
MPF	25	629.44400000	133.61529067	278.90000000	799.8000000	26.72305813	15736.100000	17853.04590
FPK	25	286.40000000	229.82602116	108.00000000	956.0000000	45.96520423	7160.000000	52820.00000
FMAX	25	1216.48000000	321.87848639	604.00000000	1488.0000000	64.37569728	30412.000000	103605.76000

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=C								
FVC	22	77.00000000	0.00000000	77.00000000	77.00000000	0.00000000	1694.000000	0.000000
FEV1	22	78.00000000	0.00000000	78.00000000	78.00000000	0.00000000	1716.000000	0.000000
FEV1P	22	99.00000000	0.00000000	99.00000000	99.00000000	0.00000000	2178.000000	0.000000
MPF	22	408.67727273	69.62449577	217.60000000	476.90000000	14.84399237	8990.900000	4847.570411
FPK	22	472.00000000	171.12290209	76.00000000	608.00000000	36.48352531	10384.000000	29283.047619
FMAX	22	620.72727273	18.00048099	584.00000000	684.00000000	3.83771544	13656.000000	324.017316
ID=D								
FVC	16	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	1632.000000	0.00000
FEV1	16	100.00000000	0.00000000	100.00000000	100.00000000	0.00000000	1600.000000	0.00000
FEV1P	16	97.00000000	0.00000000	97.00000000	97.00000000	0.00000000	1552.000000	0.00000
MPF	16	353.86250000	82.81757362	236.20000000	495.60000000	20.70439340	5661.800000	6858.75050
FPK	16	217.75000000	53.42596123	100.00000000	292.00000000	13.35649031	3484.000000	2854.33333
FMAX	16	855.75000000	354.62496622	392.00000000	1360.00000000	88.65624156	13692.000000	125758.86667
ID=E								
FVC	26	90.00000000	0.00000000	90.00000000	90.00000000	0.00000000	2340.000000	0.000000
FEV1	26	72.00000000	0.00000000	72.00000000	72.00000000	0.00000000	1872.000000	0.000000
FEV1P	26	81.00000000	0.00000000	81.00000000	81.00000000	0.00000000	2106.000000	0.000000
MPF	26	271.19615385	97.50866825	129.50000000	558.70000000	19.12302316	7051.100000	9507.940385
FPK	26	195.84615385	174.22185679	68.00000000	676.00000000	34.16771721	5092.000000	30353.255385
FMAX	26	510.30769231	200.68418358	128.00000000	724.00000000	39.35740647	13268.000000	40274.141538
ID=F								
FVC	30	146.00000000	0.00000000	146.00000000	146.00000000	0.00000000	4380.000000	0.000000
FEV1	30	141.00000000	0.00000000	141.00000000	141.00000000	0.00000000	4230.000000	0.000000
FEV1P	30	97.00000000	0.00000000	97.00000000	97.00000000	0.00000000	2910.000000	0.000000
MPF	30	185.28666667	29.73376965	129.40000000	246.10000000	5.42861879	5558.600000	884.097057
FPK	30	121.33333333	30.14142908	80.00000000	176.00000000	5.50304687	3640.000000	908.505747
FMAX	30	360.93333333	178.93688607	148.00000000	632.00000000	32.66925629	10828.000000	32018.409195

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=G								
FVC	21	91.00000000	0.00000000	91.00000000	91.00000000	0.00000000	1911.000000	0.000000
FEV1	21	78.00000000	0.00000000	78.00000000	78.00000000	0.00000000	1638.000000	0.000000
FEV1P	21	118.00000000	0.00000000	118.00000000	118.00000000	0.00000000	2478.000000	0.000000
MPF	21	291.13333333	77.16794239	117.70000000	405.20000000	16.83942558	6113.800000	5954.891333
FPK	21	163.61904762	44.71965585	80.00000000	224.00000000	9.75862895	3436.000000	1999.847619
FMAX	21	595.23809524	232.48782866	124.00000000	788.00000000	50.73300348	12500.000000	54050.590476
ID=H								
FVC	24	114.00000000	0.00000000	114.00000000	114.0000000	0.00000000	2736.000000	0.00000
FEV1	24	110.00000000	0.00000000	110.00000000	110.0000000	0.00000000	2640.000000	0.00000
FEV1P	24	96.00000000	0.00000000	96.00000000	96.0000000	0.00000000	2304.000000	0.00000
MPF	24	406.25416667	60.48871960	246.80000000	482.0000000	12.34720819	9750.100000	3658.88520
FPK	24	148.50000000	45.88549074	92.00000000	260.0000000	9.36633658	3564.000000	2105.47826
FMAX	24	432.00000000	370.00963560	256.00000000	1400.0000000	75.52790059	10368.000000	136907.13043
ID=I								
FVC	24	112.00000000	0.00000000	112.00000000	112.00000000	0.00000000	2688.000000	0.000000
FEV1	24	118.00000000	0.00000000	118.00000000	118.00000000	0.00000000	2832.000000	0.000000
FEV1P	24	105.00000000	0.00000000	105.00000000	105.00000000	0.00000000	2520.000000	0.000000
MPF	24	420.32916667	51.46431840	298.30000000	514.60000000	10.50511000	10087.900000	2648.576069
FPK	24	412.50000000	249.80079020	84.00000000	668.00000000	50.99037278	9900.000000	62400.434783
FMAX	24	724.00000000	47.66550115	624.00000000	788.00000000	9.72967968	17376.000000	2272.000000
ID=K								
FVC	20	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	2040.000000	0.000000
FEV1	20	105.00000000	0.00000000	105.00000000	105.00000000	0.00000000	2100.000000	0.000000
FEV1P	20	104.00000000	0.00000000	104.00000000	104.00000000	0.00000000	2080.000000	0.000000
MPF	20	361.54000000	32.56522847	288.90000000	412.00000000	7.28180646	7230.800000	1060.494105
FPK	20	401.00000000	196.13904842	148.00000000	596.00000000	43.85802453	8020.000000	38470.526316
FMAX	20	605.20000000	6.63007502	592.00000000	616.00000000	1.48252984	12104.000000	43.957895

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=L								
FVC	20	110.00000000	0.00000000	110.00000000	110.00000000	0.00000000	2200.000000	0.0000000
FEV1	20	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	2040.000000	0.0000000
FEV1P	20	92.00000000	0.00000000	92.00000000	92.00000000	0.00000000	1840.000000	0.0000000
MPF	20	406.78000000	23.51500305	350.10000000	440.60000000	5.25811453	8135.600000	552.9553684
FPK	20	473.20000000	78.50283267	152.00000000	532.00000000	17.55376703	9464.000000	6162.6947368
FMAX	20	598.80000000	17.41626584	560.00000000	624.00000000	3.89439543	11976.000000	303.3263158
ID=M								
FVC	28	53.00000000	0.00000000	53.00000000	53.00000000	0.00000000	1484.000000	0.000000
FEV1	28	38.00000000	0.00000000	38.00000000	38.00000000	0.00000000	1064.000000	0.000000
FEV1P	28	68.00000000	0.00000000	68.00000000	68.00000000	0.00000000	1904.000000	0.000000
MPF	28	226.03928571	54.01982036	117.90000000	351.60000000	10.20878647	6329.100000	2918.140992
FPK	28	122.14285714	114.32238830	68.00000000	576.00000000	21.60490062	3420.000000	13069.608466
FMAX	28	525.71428571	167.30518956	116.00000000	616.00000000	31.61770890	14720.000000	27991.026455
ID=N								
FVC	28	91.00000000	0.00000000	91.00000000	91.00000000	0.00000000	2548.000000	0.000000
FEV1	28	97.00000000	0.00000000	97.00000000	97.00000000	0.00000000	2716.000000	0.000000
FEV1P	28	107.00000000	0.00000000	107.00000000	107.00000000	0.00000000	2996.000000	0.000000
MPF	28	350.66071429	42.73994003	258.50000000	498.20000000	8.07708945	9818.500000	1826.702474
FPK	28	336.14285714	176.43878684	112.00000000	608.00000000	33.34379654	9412.000000	31130.645503
FMAX	28	616.57142857	30.74799430	564.00000000	736.00000000	5.81082473	17264.000000	945.439153
ID=P								
FVC	40	73.00000000	0.00000000	73.00000000	73.0000000	0.00000000	2920.000000	0.00000
FEV1	40	32.00000000	0.00000000	32.00000000	32.0000000	0.00000000	1280.000000	0.00000
FEV1P	40	44.00000000	0.00000000	44.00000000	44.0000000	0.00000000	1760.000000	0.00000
MPF	40	391.47500000	119.60227197	154.10000000	625.3000000	18.91077964	15659.000000	14304.70346
FPK	40	138.40000000	47.58625098	60.00000000	292.0000000	7.52404692	5536.000000	2264.45128
FMAX	40	856.30000000	487.98351170	172.00000000	1452.0000000	77.15696788	34252.000000	238127.90769

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=Q								
FVC	36	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	3672.000000	0.000000
FEV1	36	83.00000000	0.00000000	83.00000000	83.00000000	0.00000000	2988.000000	0.000000
FEV1P	36	81.00000000	0.00000000	81.00000000	81.00000000	0.00000000	2916.000000	0.000000
MPF	36	213.10555556	86.25402001	95.20000000	417.00000000	14.37567000	7671.800000	7439.755968
FPK	36	161.33333333	179.20969362	60.00000000	600.00000000	29.86828227	5808.000000	32116.114286
FMAX	36	551.44444444	152.56182718	104.00000000	628.00000000	25.42697120	19852.000000	23275.111111
ID=S								
FVC	27	92.00000000	0.00000000	92.00000000	92.0000000	0.00000000	2484.000000	0.00000
FEV1	27	95.00000000	0.00000000	95.00000000	95.0000000	0.00000000	2565.000000	0.00000
FEV1P	27	103.00000000	0.00000000	103.00000000	103.0000000	0.00000000	2781.000000	0.00000
MPF	27	366.53703704	142.68821888	129.60000000	695.6000000	27.46036053	9896.500000	20359.92781
FPK	27	142.96296296	130.02528792	56.00000000	600.0000000	25.02337833	3860.000000	16906.57550
FMAX	27	651.55555556	423.29452679	168.00000000	1428.0000000	81.46306966	17592.000000	179178.25641
ID=T								
FVC	36	83.00000000	0.00000000	83.00000000	83.00000000	0.00000000	2988.000000	0.000000
FEV1	36	76.00000000	0.00000000	76.00000000	76.00000000	0.00000000	2736.000000	0.000000
FEV1P	36	91.00000000	0.00000000	91.00000000	91.00000000	0.00000000	3276.000000	0.000000
MPF	36	281.48611111	102.53018274	94.60000000	414.60000000	17.08836379	10133.500000	10512.438373
FPK	36	316.88888889	246.91395584	76.00000000	592.00000000	41.15232597	11408.000000	60966.501587
FMAX	36	541.11111111	152.20020232	112.00000000	616.00000000	25.36670039	19480.000000	23164.901587
ID=U								
FVC	23	73.00000000	0.00000000	73.00000000	73.00000000	0.00000000	1679.0000000	0.000000
FEV1	23	66.00000000	0.00000000	66.00000000	66.00000000	0.00000000	1518.0000000	0.000000
FEV1P	23	90.00000000	0.00000000	90.00000000	90.00000000	0.00000000	2070.0000000	0.000000
MPF	23	145.09130435	44.57346248	96.90000000	262.00000000	9.29420941	3337.1000000	1986.793557
FPK	23	95.30434783	20.31218797	68.00000000	172.00000000	4.23538397	2192.0000000	412.584980
FMAX	23	217.56521739	117.78401886	100.00000000	560.00000000	24.55966568	5004.0000000	13873.075099

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=V								
FVC	24	101.00000000	0.00000000	101.00000000	101.00000000	0.00000000	2424.000000	0.000000
FEV1	24	106.00000000	0.00000000	106.00000000	106.00000000	0.00000000	2544.000000	0.000000
FEV1P	24	104.00000000	0.00000000	104.00000000	104.00000000	0.00000000	2496.000000	0.000000
MPF	24	280.37083333	92.52394510	132.20000000	434.60000000	18.88637121	6728.900000	8560.680417
FPK	24	300.33333333	254.45434658	88.00000000	628.00000000	51.94027600	7208.000000	64747.014493
FMAX	24	497.66666667	214.76917167	144.00000000	740.00000000	43.83957359	11944.000000	46125.797101
ID=W								
FVC	22	107.00000000	0.00000000	107.00000000	107.0000000	0.00000000	2354.000000	0.00000
FEV1	22	114.00000000	0.00000000	114.00000000	114.0000000	0.00000000	2508.000000	0.00000
FEV1P	22	106.00000000	0.00000000	106.00000000	106.0000000	0.00000000	2332.000000	0.00000
MPF	22	303.75454545	78.07004625	148.90000000	475.7000000	16.64458979	6682.600000	6094.93212
FPK	22	137.81818182	48.78293648	84.00000000	260.0000000	10.40055700	3032.000000	2379.77489
FMAX	22	485.63636364	332.14720567	192.00000000	1404.0000000	70.81402218	10684.000000	110321.76623
ID=X								
FVC	20	93.00000000	0.00000000	93.00000000	93.00000000	0.00000000	1860.0000000	0.000000
FEV1	20	78.00000000	0.00000000	78.00000000	78.00000000	0.00000000	1560.0000000	0.000000
FEV1P	20	85.00000000	0.00000000	85.00000000	85.00000000	0.00000000	1700.0000000	0.000000
MPF	20	247.37500000	54.14529065	141.00000000	356.50000000	12.10725506	4947.5000000	2931.712500
FPK	20	118.20000000	32.45661071	80.00000000	196.00000000	7.25751879	2364.0000000	1053.431579
FMAX	20	474.80000000	209.32412540	120.00000000	772.00000000	46.80629737	9496.0000000	43816.589474
ID=Y								
FVC	33	101.00000000	0.00000000	101.00000000	101.0000000	0.00000000	3333.000000	0.000000
FEV1	33	113.00000000	0.00000000	113.00000000	113.0000000	0.00000000	3729.000000	0.000000
FEV1P	33	113.00000000	0.00000000	113.00000000	113.0000000	0.00000000	3729.000000	0.000000
MPF	33	253.61515152	127.52452980	107.60000000	523.5000000	22.19917122	8369.300000	16262.505701
FPK	33	109.09090909	34.63051728	76.00000000	252.0000000	6.02839927	3600.000000	1199.272727
FMAX	33	371.87878788	310.57122347	140.00000000	1364.0000000	54.06351059	12272.000000	96454.484848

APPENDIX G

INSPIRATION REGRESSION ANALYSIS DATA

14 Abnormals (STATE=0)

P
Q
T
U
X
+

M
C
D
G
S
B
E

10 Normals (STATE=1)

H
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V
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K
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INSPIRATION REGRESSION ANALYSIS DATA.

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=+								
FVC	20	72.00000000	0.00000000	72.00000000	72.00000000	0.00000000	1440.0000000	0.00000000
FEV1	20	58.00000000	0.00000000	58.00000000	58.00000000	0.00000000	1160.0000000	0.00000000
FEV1P	20	124.00000000	0.00000000	124.00000000	124.00000000	0.00000000	2480.0000000	0.00000000
MPF	20	139.52000000	25.94333096	98.80000000	196.30000000	5.80110516	2790.4000000	673.05642105
FPK	20	98.00000000	13.26649916	68.00000000	120.00000000	2.96647939	1960.0000000	176.00000000
FMAX	20	156.00000000	21.71586856	108.00000000	204.00000000	4.85581583	3120.0000000	471.57894737
ID=*								
FVC	39	99.00000000	0.00000000	99.00000000	99.0000000	0.00000000	3861.000000	0.00000
FEV1	39	105.00000000	0.00000000	105.00000000	105.0000000	0.00000000	4095.000000	0.00000
FEV1P	39	105.00000000	0.00000000	105.00000000	105.0000000	0.00000000	4095.000000	0.00000
MPF	39	366.87179487	34.45553159	278.50000000	429.3000000	5.51730066	14308.000000	1187.18366
FPK	39	117.74615385	18.46212120	92.00000000	172.0000000	2.95630538	4592.100000	340.84992
FMAX	39	591.38461538	446.01773716	172.00000000	1296.0000000	71.41999682	23064.000000	198931.82186
ID=#								
FVC	21	70.00000000	0.00000000	70.00000000	70.0000000	0.00000000	1470.000000	0.00000
FEV1	21	74.00000000	0.00000000	74.00000000	74.0000000	0.00000000	1554.000000	0.00000
FEV1P	21	106.00000000	0.00000000	106.00000000	106.0000000	0.00000000	2226.000000	0.00000
MPF	21	300.14761905	87.00586543	140.70000000	449.5000000	18.98623639	6303.100000	7570.02062
FPK	21	115.61904762	21.46270298	80.00000000	152.0000000	4.68354576	2428.000000	460.64762
FMAX	21	636.76190476	409.52385825	152.00000000	1340.0000000	89.36543235	13372.000000	167709.79048
ID=B								
FVC	17	82.00000000	0.00000000	82.0000000	82.0000000	0.00000000	1394.000000	0.00000
FEV1	17	70.00000000	0.00000000	70.0000000	70.0000000	0.00000000	1190.000000	0.00000
FEV1P	17	85.00000000	0.00000000	85.0000000	85.0000000	0.00000000	1445.000000	0.00000
MPF	17	895.76470588	103.93119684	704.2000000	1129.0000000	25.20701779	15228.000000	10801.69368
FPK	17	740.94117647	614.01714864	112.0000000	1492.0000000	148.92103293	12596.000000	377017.05882
FMAX	17	1489.41176471	10.57744548	1464.0000000	1496.0000000	2.56540735	25320.000000	111.88235

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=C								
FVC	13	77.00000000	0.00000000	77.00000000	77.00000000	0.00000000	1001.0000000	0.000000
FEV1	13	78.00000000	0.00000000	78.00000000	78.00000000	0.00000000	1014.0000000	0.000000
FEV1P	13	99.00000000	0.00000000	99.00000000	99.00000000	0.00000000	1287.0000000	0.000000
MPF	13	414.80000000	35.87680309	329.30000000	455.40000000	9.95043486	5392.4000000	1287.145000
FPK	13	488.61538462	185.03942754	104.00000000	696.00000000	51.32070338	6352.0000000	34239.589744
FMAX	13	673.53846154	64.92125408	588.00000000	788.00000000	18.00591619	8756.0000000	4214.769231
ID=D								
FVC	19	102.00000000	0.00000000	102.00000000	102.0000000	0.00000000	1938.000000	0.00000
FEV1	19	100.00000000	0.00000000	100.00000000	100.0000000	0.00000000	1900.000000	0.00000
FEV1P	19	97.00000000	0.00000000	97.00000000	97.0000000	0.00000000	1843.000000	0.00000
MPF	19	444.64210526	130.23281851	223.60000000	672.0000000	29.87745763	8448.200000	16960.58702
FPK	19	231.78947368	232.74773634	100.00000000	740.0000000	53.39599274	4404.000000	54171.50877
FMAX	19	928.00000000	481.16525228	180.00000000	1488.0000000	110.38687946	17632.000000	231520.00000
ID=E								
FVC	19	90.00000000	0.00000000	90.00000000	90.00000000	0.00000000	1710.000000	0.000000
FEV1	19	72.00000000	0.00000000	72.00000000	72.00000000	0.00000000	1368.000000	0.000000
FEV1P	19	81.00000000	0.00000000	81.00000000	81.00000000	0.00000000	1539.000000	0.000000
MPF	19	374.44210526	35.47777576	302.50000000	430.00000000	8.13915996	7114.400000	1258.672573
FPK	19	250.31578947	185.74207105	100.00000000	616.00000000	42.61215354	4756.000000	34500.116959
FMAX	19	682.52631579	49.78550483	600.00000000	748.00000000	11.42157813	12968.000000	2478.596491
ID=F								
FVC	28	146.00000000	0.00000000	146.00000000	146.0000000	0.00000000	4088.000000	0.000000
FEV1	28	141.00000000	0.00000000	141.00000000	141.0000000	0.00000000	3948.000000	0.000000
FEV1P	28	97.00000000	0.00000000	97.00000000	97.0000000	0.00000000	2716.000000	0.000000
MPF	28	317.27857143	100.21188426	172.60000000	624.7000000	18.93826601	8883.800000	10042.421746
FPK	28	174.57142857	241.48482485	100.00000000	1028.0000000	45.63634228	4888.000000	58314.920635
FMAX	28	594.71428571	276.14500447	172.00000000	1228.0000000	52.18650054	16652.000000	76256.063492

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
				ID=G				
FVC	17	78.00000000	0.00000000	78.00000000	78.0000000	0.00000000	1326.000000	0.000000
FEV1	17	91.00000000	0.00000000	91.00000000	91.0000000	0.00000000	1547.000000	0.000000
FEV1P	17	118.00000000	0.00000000	118.00000000	118.0000000	0.00000000	2006.000000	0.000000
MPF	17	426.62352941	50.04241363	343.70000000	513.2000000	12.13706807	7252.600000	2504.243162
FPK	17	269.64705882	195.38709693	100.00000000	708.0000000	47.38833168	4584.000000	38176.117647
FMAX	17	798.58823529	110.03582304	712.00000000	1024.0000000	26.68760712	13576.000000	12107.882353
				ID=H				
FVC	18	114.00000000	0.00000000	114.00000000	114.0000000	0.00000000	2052.000000	0.000000
FEV1	18	110.00000000	0.00000000	110.00000000	110.0000000	0.00000000	1980.000000	0.000000
FEV1P	18	96.00000000	0.00000000	96.00000000	96.0000000	0.00000000	1728.000000	0.000000
MPF	18	619.09444444	51.94969821	513.10000000	689.2000000	12.24466129	11143.700000	2698.771144
FPK	18	225.77777778	40.58912569	172.00000000	260.0000000	9.56694867	4064.000000	1647.477124
FMAX	18	1322.22222222	273.43298040	260.00000000	1472.0000000	64.44877155	23800.000000	74765.594771
				ID=I				
FVC	29	112.00000000	0.00000000	112.00000000	112.0000000	0.00000000	3248.000000	0.00000
FEV1	29	118.00000000	0.00000000	118.00000000	118.0000000	0.00000000	3422.000000	0.00000
FEV1P	29	105.00000000	0.00000000	105.00000000	105.0000000	0.00000000	3045.000000	0.00000
MPF	29	542.03793103	111.10369807	368.30000000	828.8000000	20.63143879	15719.100000	12344.03172
FPK	29	500.68965517	239.33734462	152.00000000	1364.0000000	44.44382915	14520.000000	57282.36453
FMAX	29	998.89655172	319.32589095	632.00000000	1484.0000000	59.29732931	28968.000000	101969.02463
				ID=K				
FVC	22	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	2244.000000	0.000000
FEV1	22	105.00000000	0.00000000	105.00000000	105.00000000	0.00000000	2310.000000	0.000000
FEV1P	22	104.00000000	0.00000000	104.00000000	104.00000000	0.00000000	2288.000000	0.000000
MPF	22	358.01363636	63.28513927	220.20000000	445.60000000	13.49243703	7876.300000	4005.008853
FPK	22	371.81818182	166.13237303	88.00000000	532.00000000	35.41954094	8180.000000	27599.965368
FMAX	22	598.00000000	9.62140471	580.00000000	612.00000000	2.05129038	13156.000000	92.571429

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=L								
FVC	20	110.00000000	0.00000000	110.00000000	110.00000000	0.00000000	2200.000000	0.0000000
FEV1	20	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	2040.000000	0.0000000
FEV1P	20	92.00000000	0.00000000	92.00000000	92.00000000	0.00000000	1840.000000	0.0000000
MPF	20	384.79500000	38.62565925	302.50000000	435.80000000	8.63695998	7695.900000	1491.9415526
FPK	20	488.00000000	17.45972810	460.00000000	520.00000000	3.90411389	9760.000000	304.8421053
FMAX	20	587.00000000	33.36244343	536.00000000	644.00000000	7.46006914	11740.000000	1113.0526316
ID=M								
FVC	24	53.00000000	0.00000000	53.00000000	53.00000000	0.00000000	1272.000000	0.000000
FEV1	24	38.00000000	0.00000000	38.00000000	38.00000000	0.00000000	912.000000	0.000000
FEV1P	24	68.00000000	0.00000000	68.00000000	68.00000000	0.00000000	1632.000000	0.000000
MPF	24	271.51250000	68.68549820	154.80000000	396.30000000	14.02036861	6516.300000	4717.697663
FPK	24	227.66666667	210.93882622	72.00000000	588.00000000	43.05770760	5464.000000	44495.188406
FMAX	24	549.33333333	129.26368960	140.00000000	624.00000000	26.38584015	13184.000000	16709.101449
ID=N								
FVC	25	91.00000000	0.00000000	91.00000000	91.00000000	0.00000000	2275.000000	0.000000
FEV1	25	97.00000000	0.00000000	97.00000000	97.00000000	0.00000000	2425.000000	0.000000
FEV1P	25	107.00000000	0.00000000	107.00000000	107.00000000	0.00000000	2675.000000	0.000000
MPF	25	384.89600000	38.76268051	256.40000000	435.60000000	7.75253610	9622.400000	1502.545400
FPK	25	440.48000000	154.66660920	100.00000000	616.00000000	30.93332184	11012.000000	23921.760000
FMAX	25	635.68000000	23.69022302	588.00000000	688.00000000	4.73804460	15892.000000	561.226667
ID=P								
FVC	25	73.00000000	0.00000000	73.00000000	73.0000000	0.00000000	1825.000000	0.00000
FEV1	25	32.00000000	0.00000000	32.00000000	32.0000000	0.00000000	800.000000	0.00000
FEV1P	25	44.00000000	0.00000000	44.00000000	44.0000000	0.00000000	1100.000000	0.00000
MPF	25	455.16800000	158.40528116	255.50000000	822.6000000	31.68105623	11379.200000	25092.23310
FPK	25	199.36000000	234.67901483	84.00000000	1316.0000000	46.93580297	4984.000000	55074.24000
FMAX	25	964.96000000	511.66822584	240.00000000	1484.0000000	102.33364517	24124.000000	261804.37333

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=Q								
FVC	37	102.00000000	0.00000000	102.00000000	102.00000000	0.00000000	3774.000000	0.000000
FEV1	37	83.00000000	0.00000000	83.00000000	83.00000000	0.00000000	3071.000000	0.000000
FEV1P	37	81.00000000	0.00000000	81.00000000	81.00000000	0.00000000	2997.000000	0.000000
MPF	37	205.61081081	89.43860335	94.50000000	453.00000000	14.70361582	7607.600000	7999.263769
FPK	37	141.18918919	164.04027924	56.00000000	608.00000000	26.96805578	5224.000000	26909.213213
FMAX	37	536.21621622	182.55457862	108.00000000	680.00000000	30.01178785	19840.000000	33326.174174
ID=S								
FVC	19	92.00000000	0.00000000	92.00000000	92.0000000	0.00000000	1748.000000	0.00000
FEV1	19	95.00000000	0.00000000	95.00000000	95.0000000	0.00000000	1805.000000	0.00000
FEV1P	19	103.00000000	0.00000000	103.00000000	103.0000000	0.00000000	1957.000000	0.00000
MPF	19	414.11052632	176.26240821	183.60000000	785.3000000	40.43736973	7868.100000	31068.43655
FPK	19	175.15789474	186.16398481	76.00000000	928.0000000	42.70894720	3328.000000	34657.02924
FMAX	19	692.84210526	462.27376006	144.00000000	1436.0000000	106.05287391	13164.000000	213697.02924
ID=T								
FVC	31	83.00000000	0.00000000	83.00000000	83.0000000	0.00000000	2573.000000	0.000000
FEV1	31	76.00000000	0.00000000	76.00000000	76.0000000	0.00000000	2356.000000	0.000000
FEV1P	31	91.00000000	0.00000000	91.00000000	91.0000000	0.00000000	2821.000000	0.000000
MPF	31	259.19032258	106.68721371	98.70000000	419.7000000	19.16158924	8034.900000	11382.161570
FPK	31	197.41935484	180.14378964	76.00000000	592.0000000	32.35477975	6120.000000	32451.784946
FMAX	31	603.87096774	293.31663687	124.00000000	1224.0000000	52.68122315	18720.000000	86034.649462
ID=U								
FVC	22	73.00000000	0.00000000	73.00000000	73.0000000	0.00000000	1606.0000000	0.000000
FEV1	22	66.00000000	0.00000000	66.00000000	66.0000000	0.00000000	1452.0000000	0.000000
FEV1P	22	90.00000000	0.00000000	90.00000000	90.0000000	0.00000000	1980.0000000	0.000000
MPF	22	154.65454545	62.88946257	93.80000000	350.3000000	13.40807847	3402.4000000	3955.084502
FPK	22	89.45454545	13.72077768	52.00000000	108.0000000	2.92527963	1968.0000000	188.259740
FMAX	22	277.63636364	277.33880697	104.00000000	1352.0000000	59.12883232	6108.0000000	76916.813853

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
ID=V								
FVC	27	101.00000000	0.00000000	101.00000000	101.00000000	0.00000000	2727.000000	0.000000
FEV1	27	106.00000000	0.00000000	106.00000000	106.00000000	0.00000000	2862.000000	0.000000
FEV1P	27	104.00000000	0.00000000	104.00000000	104.00000000	0.00000000	2808.000000	0.000000
MPF	27	303.12962963	103.89385417	157.10000000	494.90000000	19.99438156	8184.500000	10793.932934
FPK	27	262.37037037	240.07244870	76.00000000	644.00000000	46.20196429	7084.000000	57634.780627
FMAX	27	532.88888889	199.77012430	156.00000000	692.00000000	38.44577835	14388.000000	39908.102564
ID=W								
FVC	21	107.00000000	0.00000000	107.00000000	107.00000000	0.00000000	2247.0000000	0.000000
FEV1	21	114.00000000	0.00000000	114.00000000	114.00000000	0.00000000	2394.0000000	0.000000
FEV1P	21	106.00000000	0.00000000	106.00000000	106.00000000	0.00000000	2226.0000000	0.000000
MPF	21	280.01904762	88.57784497	134.90000000	453.40000000	19.32927045	5880.4000000	7846.034619
FPK	21	125.71428571	36.80372652	76.00000000	260.00000000	8.03123155	2640.0000000	1354.514286
FMAX	21	423.80952381	145.70916891	172.00000000	660.00000000	31.79634743	8900.0000000	21231.161905
ID=X								
FVC	25	93.00000000	0.00000000	93.00000000	93.00000000	0.00000000	2325.0000000	0.000000
FEV1	25	78.00000000	0.00000000	78.00000000	78.00000000	0.00000000	1950.0000000	0.000000
FEV1P	25	85.00000000	0.00000000	85.00000000	85.00000000	0.00000000	2125.0000000	0.000000
MPF	25	188.77600000	63.49351200	105.50000000	365.80000000	12.69870240	4719.4000000	4031.426067
FPK	25	105.92000000	19.93723485	64.00000000	164.00000000	3.98744697	2648.0000000	397.493333
FMAX	25	250.72000000	125.70717296	136.00000000	568.00000000	25.14143459	6268.0000000	15802.293333
ID=Y								
FVC	23	101.00000000	0.00000000	101.00000000	101.0000000	0.00000000	2323.0000000	0.000000
FEV1	23	113.00000000	0.00000000	113.00000000	113.0000000	0.00000000	2599.0000000	0.000000
FEV1P	23	113.00000000	0.00000000	113.00000000	113.0000000	0.00000000	2599.0000000	0.000000
MPF	23	214.54347826	112.65157396	114.10000000	481.2000000	23.48947694	4934.5000000	12690.377115
FPK	23	102.08695652	12.92605910	80.00000000	124.0000000	2.69526964	2348.0000000	167.083004
FMAX	23	252.34782609	224.36630129	124.00000000	1224.0000000	46.78360785	5804.0000000	50340.237154

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